Innovate:

Issue 10 2015

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UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Engineering, Built Environment and Information Technology

Fakulteit Ingenieurswese, Bou-omgewing en Inligtingtegnologie / Lefapha la Boetšenere, Tikologo ya Kago le Theknolotši ya Tshedimošo

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Innovate:

Issue 10 2015

Innovate 10: 2015

Innovate is an annual publication of the University of Pretoria's Faculty of Engineering, Built Environment and Information Technology.

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Printing:
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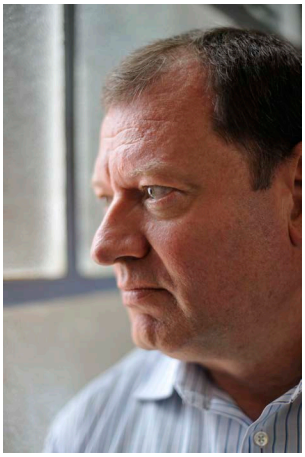
Focus on research related to the food-energy-water nexus from an engineering management perspective

The food-energy-water nexus



Over the years, the University of Pretoria has placed a high priority on teaching and research that are not only of local relevance, but also of international importance. With the ongoing changes in global needs, researchers have had to align their research programmes to ensure that they continue to address issues that are of both local and international relevance. The food-energy-water nexus is particularly pertinent in this regard.

The supply of enough electricity to satisfy the demand in South Africa is a well-known problem. Government, industry, private investors and research institutions collaborate closely to solve this very complex situation. Recently, experts in the field of water supply started raising their voices, warning about a future shortage of water in the country. One of the concerns was the demand for water from the newly planned and built electricity generation plants. At the same time, experts in the field of food research raised concerns about both the future lack of sufficient water and bio-energy sources that would erode the supply of adequate food for the country. It became clear that the series of connections between food, energy and water – the so-called food-energy-water nexus with all its complex problems – is becoming a priority issue for researchers and policy developers. There is a clear demand for researchers to look into these complex relationships and to provide solutions and policy recommendations.

A few years ago, the University established a number of high-priority research focus areas that included energy and food research. Researchers excelled above expectations in delivering research outputs. In the field of energy research, for example, the University became one of the leading publishers of articles in the country. Our researchers should, however, become aware of the importance of and need for multi-disciplinary research in order to connect different focus areas such as food, energy and water. The future needs of our country demand unique solutions to its complex problems, and our universities and other research institutions should take up the challenge as they have always done in the past.

This year we are proud to publish the 10th issue of *Innovate*. Over the years, we have shared with you the interesting research that is conducted in the Faculty of Engineering, Built Environment and Information Technology. In this issue, you will again find interesting articles on research emanating from the schools of Engineering, the Built Environment and Information Technology. The variety of topics emphasises the collaboration between our researchers. You will find interesting reading on energy, water, aeronautics, wireless telecommunications, town and regional planning, and many more. I trust you will enjoy all the contributions.

In the previous issue of *Innovate* I mentioned that the former Dean of Engineering, Built Environment and Information Technology handed over the reins to his successor, Prof Sunil Maharaj. This is undoubtedly a very challenging responsibility, but as you will notice in the article profiling his achievements, he is certainly well qualified and experienced to make a great success of this role, and has a clear vision of where he wants to take the Faculty in the years to come. High-quality research, international collaboration and world-class teaching are some of his priorities. All the colleagues in the Faculty of Engineering, Built Environment and Information Technology wish him well with his endeavours.

Editor
Tinus Pretorius

Revolutionising the education of mining engineers

The Department of Mining Engineering at the University of Pretoria has made giant strides in hybrid education models with the initiation of the Kumba Virtual Reality Centre for Mine Design. This centre marks the start of a new era in the education of students in mining engineering, graduates and practitioners, and has the potential to contribute significantly to the future of mining in South Africa and the rest of the world.

For the past three years, in partnership with Kumba Iron Ore, the Department of Mining Engineering has been hard at work developing the Kumba Virtual Reality Centre for Mine Design. This is the first centre of its kind in Africa, and enables a revolutionary way of educating students and mine staff in a simulated mining environment. The centre is the product of a R18.8 million corporate social responsibility sponsorship from Kumba Iron Ore, and has been in full operation since its launch in August 2015.

The Kumba Virtual Reality Centre for Mine Design comprises three sections, each designed and developed with the aim of providing students in mining engineering with a realistic and immersive experience of the possibilities, limitations and challenges of mine design; not only from a research perspective, but also in industry.

The first section of the centre comprises a computer-assisted lecture hall where students learn about mine design and apply their newly acquired skills to their own mine design projects.

The Kumba Virtual Reality Centre for Mine Design simulates high-risk scenarios in a safe and controlled environment.

The second section comprises a wall-to-wall 3D theatre, where student mine designs and other teaching resources can be showcased so that students can learn through a visual process. The final section of the centre provides an immersive experience, and comprises a theatre with 360º floor-to-ceiling screens inside which the virtual reality simulator casts images against the dark surrounding panels with cinematic clarity and highly realistic sound effects.

The core motivation behind the Kumba Virtual Reality Centre for Mine Design stems from Kumba's belief that all mining injuries are preventable and that much can be done in South Africa to achieve the "zero-harm" objective that is embraced by mining companies. As such, the benefactor is eager to see what can be achieved through its collaboration with the University of Pretoria, which Norman Mbazima, CEO of Kumba Iron Ore, describes as a credible partner, in realising the potential of these technological innovations.

The appeal of the centre is based on it being a low-risk, high-impact learning environment. "The Kumba Virtual Reality Centre for Mine Design simulates high-risk scenarios in a safe and controlled environment where the consequences of any unsafe act can be powerfully demonstrated without causing any actual loss of life and damage to property," says Prof Ronny Webber-Youngman, Head of the Department of Mining Engineering.

Guests at the launch of the Kumba Virtual Reality Centre for Mine Design participate in the immersive experience.

Institutional and industry collaboration

Together with the establishment of the Kumba Virtual Reality Centre for Mine Design, the Department has also established the Mining Resilience Research Institute (MRRI). This was prompted by the realisation that, for a number of complex reasons, mining in South Africa is not meeting the full expectations of all stakeholders.

Through the MRRI, which also forms part of the existing Sasol Chair in Safety, Health and Environment, the University has the potential to establish itself as a leading international contributor to solutions for complex mining industry problems through the rigorous integration of scientific research, the pursuit of practically implementable solutions and the education of graduates who are equipped with relevant skills.

The Kumba Virtual Reality Centre for Mine Design, through its utilisation of cutting-edge virtual reality technology, is capable of contributing to such research and teaching in a unique way. In practice, undergraduate students in mining engineering can integrate different conceptual and software modelling techniques, which incorporate geological models, mineral extraction methods, mine planning and design, and mining systems in a virtual reality environment.

This allows them to design a complex mining operation and virtually study its life cycle by actually seeing the long-term visual and environmental consequences of their financial and technical decisions. In addition, the centre allows for the reconstruction of mining incidents for forensic investigation purposes, and allows for the reverse engineering of mine structures to prevent dangerous incidents from occurring in future.

By improving the ability of mining engineers to take these factors into account, the centre has the ability to provide significant economic, environmental and safety benefits to the industry and the communities affected by mining operations in the real world, and thus contributes to society on various levels.

In addition to the very real benefits that the Kumba Virtual Reality Centre for Mine Design holds for the South African mining industry, its establishment also highlights the benefits of institutional and industry collaboration when it comes to solving pressing problems.

The centre is an embodiment of collaborative efforts between various disciplines. Most significantly, it emphasises the power of big data collected and collated on a large scale to find ways of addressing real problems and inform learning and practice in various industries. Prof Webber-Youngman advocated for implementing the lessons learned through the Kumba Virtual Reality Centre for Mine Design to other industries by integrating other fields of study into the virtual world of the centre.

As an expression of these institutional goals, the Faculty of Engineering,

Celebrating the official opening of the Kumba Virtual Reality Centre for Mine Design are (from left) Prof Sunil Maharaj, Dean of the Faculty of Engineering, Built Environment and Information Technology, Prof Cheryl de la Rey, Vice-Chancellor and Principal, Norman Mbazima, CEO of Kumba Iron Ore, and Prof Ronny Webber-Youngman, Head of the Department of Mining Engineering.

Built Environment and Information Technology realises that contributions to the knowledge economy from these research efforts require an essential step towards the "human economy", or a serious investment in improving human capital. The Kumba Virtual Reality Centre for Mine Design is a platform designed to close the gap between study and industry by equipping students for the realities, challenges and dangers of mining; a testimony to the University's efforts to ensure that it is not isolated from industry and that it is able to deliver graduates with relevant and implementable skills.

Ensuring relevance with a revolutionary hybrid teaching model

The Kumba Virtual Reality Centre for Mine Design signifies a huge leap in innovative education and teaching in South Africa. This is an essential characteristic of institutions that strive for relevance both in academia and in industry, and is a core strategic goal of the University. The incorporation of virtual reality technology constitutes an essential supportive resource in the immersive teaching model adopted by the Department of Mining Engineering. Essentially, this hybrid teaching model brings to life the 3D structures and principles that students traditionally had to visualise from their 2D textbooks.

Engineering subjects are highly technical, and it is often difficult for students to visualise the concepts without actually seeing them. Students can now design their mining projects on computers and see their design decisions realise in the 3D theatre where they can identify potential problems and see the effects of these problems in a simulated environment.

Prof Webber-Youngman calls the students who will participate in this teaching and learning platform "imagineers", because they will become a new generation of engineers who will be able to imagine better solutions to real-world problems.

Both the 3D theatre and the immersive mine simulation theatre allow students to visualise practical elements of their subject content. This includes elements such as the relativity and size of objects, the visual texture of material and the effect of explosions. Here, they can see exactly where they will work and what they will do before even setting foot on a real mine.

However, Prof Webber-Youngman explains that the virtual reality experience is intended to supplement actual mine visits rather than replace exposure to real mines. Virtual reality can simulate the real mining environment, but it cannot replace the experience of the real situation.

The impact that this centre will have on research and teaching in mining engineering at the University of Pretoria and the country as a whole will be invaluable.

Its optimisation of information and visualisation has made great strides towards ensuring relevant education and learning for students, and has strengthened the ability of academic research to make a positive contribution to the industry in which it operates.

→ *Students experience the Kumba Virtual Reality Centre for Mine Design.*

Producing fuel from agriculture and forestry waste

The Pyrolysis Laboratory of the University of Pretoria's Department of Chemical Engineering is generating a lot of heat. So much heat, in fact, that the research team of Prof Mike Heydenrych believes that their latest invention will soon be able to provide farmers with "green" transportation fuel produced in a reactor on their own farms from their own agricultural waste products.

Worldwide, there is a need for a renewable transportation fuel. This need is felt even more urgently in South Africa, due to its lack of natural oil resources, which results in consumers having to pay currency-related prices for this essential product. The effect of these high prices is felt most critically by farmers and rural inhabitants who have to use large amounts of fuel to plant crops or travel to market.

Prof Heydenrych has always been interested in rotary kilns and the process of subjecting materials to high temperatures (typically over 800 °C) in order to bring about a chemical or physical change. Early in 2010, his research in this field brought him into contact with Dr Akwasi Boateng of the United States Department of Agriculture, who introduced him to the process of pyrolysis. This is a chemical process that breaks down material like wood or tyres by very rapidly heating it up at temperatures of around 400 to 500 °C in an environment from which the oxygen has been removed.

Initially working with Dr Boateng, Prof Heydenrych developed a pyrolyser, using the principles of gasification developed by Prof Robin Judd, formerly of the University of Durban-Westville. The result of this research was the development of a fast pyrolysis unit that can convert dry biomass into crude oil in a single reactor.

With funding obtained from Sappi and the Paper Manufacturers Association of South Africa (PAMSA), supplemented with a Technology and Human Resources for Industry Programme (THRIP) grant, Prof Heydenrych proceeded to establish a Pyrolysis Laboratory at the University of Pretoria where his research team could build a reactor to test the viability of using forestry sawdust to produce biofuel by making use of the fast pyrolysis process they had developed. Due to South Africa's unique forestry and agriculture infrastructure, it is possible to source biofuels without seriously impacting on the existing value chain.

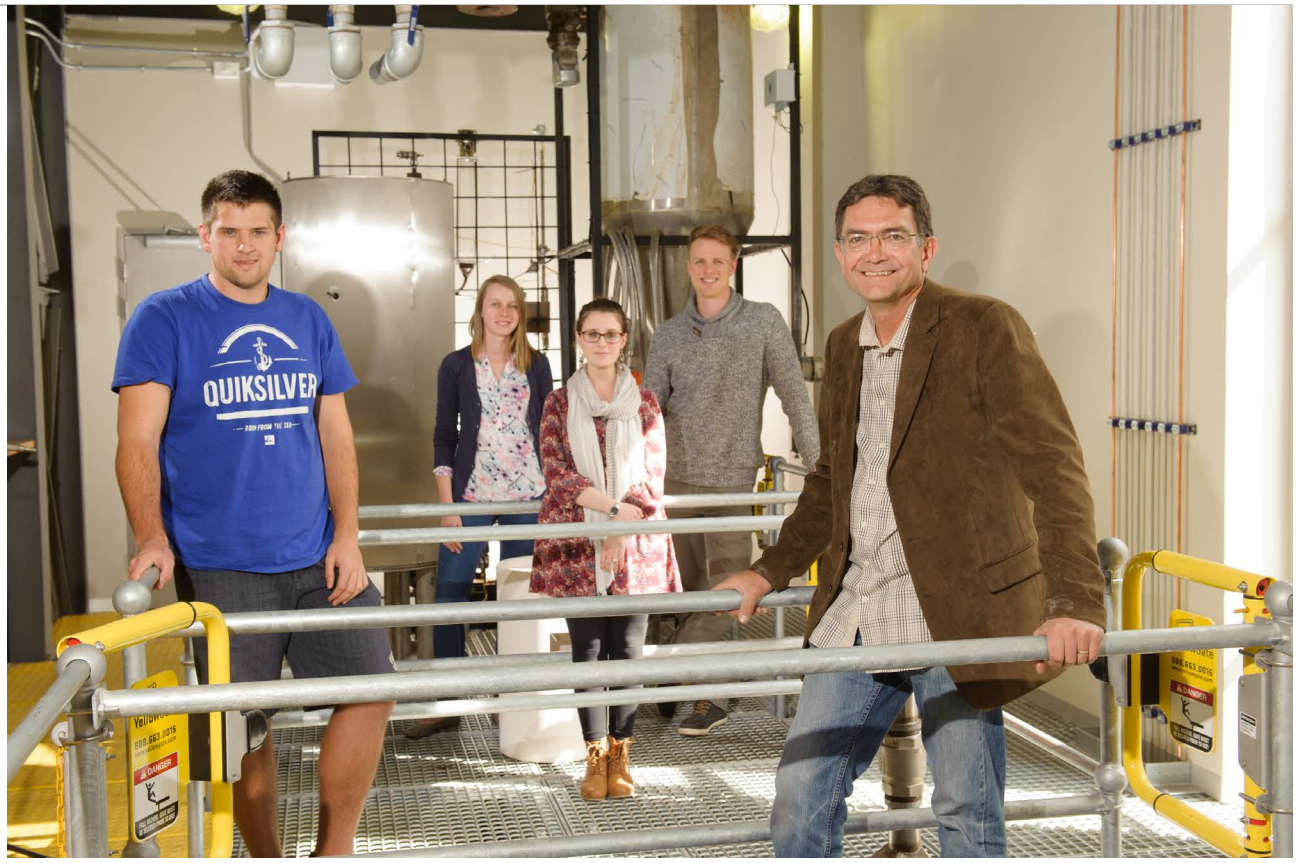
Nowhere is the need for a renewable transportation fuel more urgently felt than in South Africa.

According to Prof Heydenrych, studies suggest that by using local agriculture and forestry waste, and converting it to fuel, we would be able to supply as much as 100% of the national demand for petrol, thus reducing our dependence on non-renewable fossil fuel reserves.

Innovative technology

The advantages of the technology developed by Prof Heydenrych are threefold: Instead of burning the char (the solid material that remains after light gases and tar have been released from a carbonaceous material during the initial stage of combustion), it recovers it so that the char can be put back in the soil as mineral-rich fertilizer and mulch, making it sustainable.

The reactor can be scaled up to meet the large customer need. The design also allows for the in-situ catalysis of the product oil to convert it in a single step close to the specifications required for transportation fuels. A provisional patent for this technology was registered in 2013, with a national patent filed in the USA, Canada, Brazil,



→ *The pyrolysis team with the new pyrolyser in the Department of Chemical Engineering (from left): Johann Wauts, Lucja Wanicka, Ümit Postma, Patrick O'Brien and Prof Mike Heydenrych.*

Europe, China and South Africa.

The ultimate goal is to commercialise the technology by building small (container) and large pyrolysis units and to sell them to farmers and rural customers so that they can produce their own fuel. In time, this may lead to a rural decentralised biofuel industry. The research team believes that the real benefit of this solution lies in its size and ease of operation.

According to Prof Heydenrych's calculations, the estimated diesel input cost to farm maize is 64 litres of diesel or R820 per hectare. This means that the average farmer, farming a 1 200 hectare farm, has to pay almost R1 million for fuel to plant the crop, regardless of success or failure. From census data, there are an estimated 40 000 "average" farming units in South Africa. He is confident that such farmers would be willing to invest substantially in a pyrolysis unit. It is estimated that a fast pyrolysis unit can be built for less than R2 million with a capacity of 100 000 litres per month.

With the reactor that was designed, liquid fuel can be produced as output from the process (as opposed to gasifiers that produce gas from biomass, or bio-ethanol that typically requires food crops as a source material). Compared to gas, liquid fuel is denser with a much higher energy value, which makes it easy to transport. The process of fast pyrolysis also allows large throughputs to be processed with equipment that is relatively small, which means that a reactor can be built that may be used at the community or farm level. This unique method of providing the required energy to the reactor makes it scalable, and allows carbon molecules to be captured. This makes the entire agricultural life cycle more sustainable, and even carbon-negative overall, as the carbon is sequestrated.

Intellectual property

A second provisional patent was lodged in May 2013. This patent, which is owned by the University of Pretoria, has been lodged as a Patent Cooperation Treaty (PCT) application. This is for an improved reactor design, which involves heating the pyrolysis bed around the combustion bed, and replacing the sand in the reactor with a catalyst to upgrade the fuel. The research team is currently testing two catalysts that have been developed, and both are providing excellent results.

While the calorific value of crude oil is 45 MJ/kg, typical pyrolysis oil has a calorific value of only 20 MJ/kg, as opposed to the industry standard, using a commercially available catalyst, which is 32 MJ/kg. The results obtained using one of the catalysts developed in the Department of Chemical Engineering show that it delivers an oil with a calorific value of 39 MJ/kg, which is of a very good quality and compares very well with crude oil.

Prof Heydenrych's team is also busy developing new in-situ catalysts that will allow the product of the fast pyrolysis process to

→ *Johann Wauts measures out some bio-oil generated from sawdust.*

be upgraded into a fuel oil. Apart from the desired chemical characteristics, the catalyst must have particular physical characteristics to withstand cyclical temperature variations and the abrasion that is characteristic of fluidised beds.

The next step will be to provide proof of concept, using various feedstocks such as rubber, plastic, corn stover, bagasse and coal fines. Yields will be measured and physical samples of the various oils collected for stability tests and further end-testing.

Bringing the technology to market

The project has received seed funding to the value of R500 000 from the Technology Innovation Agency (TIA) for the commercialisation of the venture.

Blue Venture Partners (Pty) Ltd has been appointed to perform market research and conduct a needs analysis. This company will also develop a business plan with a number of business models that may be tested for viability. This will include defining the customer segment, determining the value proposition and channel relationships, and designing a revenue model and cost estimates.

This invention will enable farmers to sell their fuel into the national system.

A large-scale pilot project will be undertaken to educate customers, as well as test the viability of the business model. This will be followed by the development of commercial units for local and international rural deployment.

National benefits

This project has enormous potential to benefit the nation. By upgrading valueless biological plant waste material to high-value liquid fuel, it places the capability to produce biofuel squarely in the hands of rural communities and farmers. The pyrolyser is small and simple enough for portable units to be built.

This means that they can be manufactured centrally and placed in the hands of cooperatives, communities, farmers and small, medium and micro enterprises (SMMEs) so that they can produce their own fuel and sell this fuel into the national system. Once commercialised, it will have a massive impact on rural job creation.

The project also has the potential to develop a highly skilled capacity and knowledge base, and increase capabilities for technology innovation. Postgraduate students who have formed part of the research team and who have graduated from the University of Pretoria are currently employed in the forestry industry, with the result that technology has successfully been transferred and skills developed that will benefit the industry at large.

New early warning system may be the answer to prevent poaching and livestock theft

In light of the devastating game poaching statistics in South Africa, intruder detection on large game reserves and farms poses a challenge. To prevent poaching and livestock theft, intruders should be detected on the farm's perimeter and their position determined promptly and accurately.

A University of Pretoria graduate, Ernst Pretorius, has developed a patented early warning system that promises to be a unique, cost-effective solution to this problem. The system, called Draadsitter (Afrikaans for "fence sitter"), warns farmers of fence tampering and pinpoints the location of triggered alarms.

Pretorius obtained his degree in electronic engineering from the University of Pretoria in 1996. For his final-year project, he developed a concept for a small ultra-high frequency (UHF) transmitter that could be used as an animal tracking device. The theory was that a transceiver attached to livestock would allow farmers to track animals' movement and learn their movement habits. Any deviation from this learnt pattern would trigger an alarm to alert the farmer that his livestock may be in danger.

Inspired by an undergraduate project

While working as a power electronics engineer, Pretorius had no idea that his final-year project would eventually inspire the revolutionary Draadsitter system and lead to a nomination for the Royal Academy of Engineering Africa Prize for Engineering Innovation. The idea for the Draadsitter system came to him when a dairy farmer from Delmas told him about the problems he was experiencing with livestock theft. Pretorius realised that catching the intruders before they gained access to the property was crucial in the prevention of livestock theft and the resulting cruelty to the animals. Although his UHF transmitter concept showed potential, the alarm would only be triggered once the intruders had already gained access to the livestock. Livestock enclosures are often some distance from the farmhouse, and the time it takes to react may give the intruders enough time to escape.

He thought of using sound waves to develop a sensor unit that would alert the farmer of any fence tampering.

Pretorius knew that the solution to this problem lay in the wire perimeter fences, which could be excellent conductors of sound. He thought of using sound waves to develop a sensor unit that would alert the farmer of any fence tampering. Other options for intruder detection on the market exhibited some drawbacks, such as high maintenance costs and repair complexity. Pretorius was confident that he could develop a system without these drawbacks, and started developing the Draadsitter system in 2013.

How it works

The sensor unit consists of two sensors, and the unit is mounted onto the fence's wiring posts. The first sensor measures only the ambient sound. The other sensor measures both the ambient sound and additional sounds on the fence. This is transmitted through the wire via longitudinal sound waves that propagate within the wire of the fence. The difference between the two measurements is determined and an alarm is triggered when the difference between the sensor readings falls outside a pre-set range. As a result, unrelated sounds like thunder or the sound of a vehicle cannot trigger false alarms, but noises associated with fence tampering are amplified.

The system's base unit, which is typically set up in an office or a farmhouse, displays the address of the sensor that triggered the alarm. This allows farmers or landowners to react before any animals are stolen or harmed. When a fence is cut, the sensor unit can regain full functionality once the fence is repaired. This also saves costs, because repairs do not require specialists, as in the case of fibre optics or electric fencing.

The system can accommodate up to 9 999 sensor units that are linked to each other via a secure radio network. The units are mounted onto the fence's wiring posts and fence lengths of over 1 000 km can be monitored using a single system.

Turning an idea into a viable invention

The first prototype was tested on an old fence and could detect tampering up to 50 m. Although initially developed with cattle farmers in mind, the potential of the unit for protecting game reserves, and also for border fences, soon became evident. Word of the potential of the Draadsitter system spread and queries about his invention prompted Pretorius to take six months' unpaid leave from his employer at the time, Denel Dynamics, to develop it further. He registered a provisional patent, and spent all his time refining his invention. During this time, he changed the system so that it could use AA batteries, which would keep the sensors running for more than two years at a time. This ensured constant functionality, as the system did not depend on an external power supply. He also used a cost-effective plastic casing to house the sensor unit.

During the research and development phase of his invention, the sensor unit was tested on the electric fence surrounding the perimeter of a game reserve. The electric field of the high voltage triggered false alarms in the sensors. Pretorius therefore encapsulated the unit in a metal box – as in a Faraday cage[1] – to shield the sensors from this electric field. He also incorporated a temperature sensor in the unit to warn users of possible fires when it senses a temperature above 65 °C. Subsequent prototypes were tested on a number of fences.

The electric field of the high voltage triggered false alarms in the sensors.

The development of the system faced a number of challenges, including financial constraints. Unlike inventors who have the support of an academic or research institution, Pretorius developed his innovation on his own, without any investors to provide seed funding or financial support for the project. However, his belief in his concept and determination to prevent unnecessary cruelty to animals spurred him on. Aside from the prize money he received as one of the four finalists for the Royal Academy of Engineering Africa Prize for Engineering Innovation Award in 2014, the project relied entirely on Pretorius's ability to finance all the development phases and patent applications himself. Draadsitter is now patented in the USA, Australia, New Zealand, Europe and 19 countries in Africa, as well as South Africa. He had to use his savings to conduct prototype demonstrations in order to commercialise his product. His perseverance paid off in the end when he was awarded a contract to install a system comprising 340 Draadsitter units on the largest rhino farm in South Africa.

Future applications

Future applications of this technology could include early warning systems to prevent copper cable theft and systems that use drones for perimeter fence surveillance. It could prove to be effective in protecting country borders from infiltration and illegal immigrants. Another possible addition to the existing system is the use of buried Piezo wires to trigger an alarm when someone passes through a gate or other entrance.

Pretorius highlights the value of the qualification that he obtained from the University of Pretoria, and has great appreciation for the qualified academic staff and high academic standards that ensure that graduates are able to enter industry as well-rounded individuals, who can see the potential in any opportunity, and have the confidence to succeed, no matter how many hurdles they might encounter.

1 *An earthed metal screen surrounding a piece of equipment to exclude electrostatic and electromagnetic influences.*


DRAADSITTER
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Faculty is positioned to meet the challenges of a knowledge economy

The Faculty of Engineering, Built Environment and Information Technology is a leading source of locally relevant and internationally competitive programmes at both undergraduate and postgraduate levels. Its School of Engineering is ranked among the top 1% of engineering schools in the world and it will be celebrating 60 years of world-class tuition in 2016.

The Faculty attracts high-quality students and staff, and offers extended programmes to facilitate inclusiveness. It is well resourced in terms of teaching and research facilities, and houses several research chairs, centres and institutes. It maintains close links with industry, which supports both teaching and research programmes. The Faculty's multidisciplinary nature facilitates interaction across disciplines in both teaching and research activities.

Over the past 15 years, the Faculty has witnessed a remarkable growth in stature, both in terms of student numbers and the diversity profile of its student corps. From about 6 000 students in 2010, the Faculty now has close to 12 000 students (of which almost 30% comprises postgraduate students), effectively doubling its student population over the past five years. In the process, it can make a direct contribution to human capital development in the scarce skills that are so desperately needed in this country. The composition of the Faculty has also changed over the years to be more representative of the country's population. More than half the students in the Faculty are from designated groups, and the Faculty's gender profile is also improving.

The Faculty's engineering programme is ranked in the top 1% in the world according to the Thomson Reuters ISI Web of Science.

Its positioning as a faculty of choice among learners, postgraduate students, parents and industry is enhanced by the ranking of its engineering programme in the top 1% in the world according to the Thomson Reuters ISI Web of Science. It has also been the highest ranked among all South African engineering schools for the past five years.

Academic programmes

The Faculty comprises four schools: the School of Engineering, the School for the Built Environment, the School of Information Technology and the Graduate School of Technology Management.

The School of Engineering offers both undergraduate and postgraduate programmes in chemical engineering, civil and biosystems engineering, electrical, electronic and computer engineering, industrial and systems


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engineering, materials science and metallurgical engineering, mechanical and aeronautical engineering, and mining engineering. Its undergraduate programmes are all accredited by the Engineering Council of South Africa (ECSA).

The School for the Built Environment is the largest of its kind in the country. Undergraduate and postgraduate degrees are offered in architecture, landscape architecture, interior architecture, quantity surveying, construction management, and town and regional planning. At postgraduate level, the School offers both honours and master's degrees in architecture, interior architecture and landscape architecture, as well as a master's degree in town and regional planning. Doctoral degrees are also offered.

The School of Information Technology is a unique institution for tertiary education in the field of information technology. Established in April 1998, it consists of the departments of Computer Science, Informatics and Information Science. Close links also exist with the Faculty's Department of Electrical, Electronic and Computer Engineering. The integration of the three academic departments in one school has brought considerable advantages for the programmes offered.

The Graduate School of Technology Management (GSTM) presents post-graduate programmes in the Department of Engineering and Technology Management. These internationally recognised development programmes are offered at honours, master's and doctoral level, and address different needs in the fields of technology management, project management, engineering management and asset management. The increasing complexity of engineering systems and activities, the scope and sophistication of resources, as well as advances in technology, have all been driving forces in the evolution of engineering and technology management as a globally evolving new discipline.

The Faculty's commitment to academic and research excellence is supported by facilities and equipment of the highest quality.

Research focus

Research and postgraduate studies are regarded as core activities of the Faculty. The research outputs of its postgraduate students and research staff have increased steadily over the past few years, making it the second-highest producer of journal article units in the University.

Almost 22% of its academics have been rated by the National Research Foundation (NRF), and it boasts three A-rated researchers: Prof Brian Rand, Chairholder of the South African Research Chairs Initiative (SARChI) Chair in Carbon Technology and Materials, Prof Xiaohua Xia, Director of the Centre of New Energy Systems and of the National Hub for Postgraduate Programme in Energy Efficiency and Demand-side Management, and Prof Andries Engelbrecht, Chairholder of the SARChI Chair in Artificial Intelligence and Head of the Department of Computer Science.

The Faculty's research activities have seen significant growth over the past few years with the establishment of several new research institutes, as well as SARChI and industry-sponsored research chairs. These include the Sasol Mining Resilience Research Institute, the SARChI Chair in Advanced Sensor Networks and the Council for Scientific and Industrial Research (CSIR) Chair in Aeronautics. Some of the Faculty's existing chairs are proud to receive ongoing support from industry. The sponsorship by Transnet of the Transnet Chair in Railway Engineering, for example, celebrated 23 years of collaborative training and research in 2015, while the Sentech Chair in Broadband Wireless Multimedia Communications (BWMC), which was launched in 2006, has received funding from its sponsor for a further four years. (See article on page 34.)

Key research clusters in the Faculty that provide multidisciplinary research opportunities and are focused on addressing national, regional and global challenges include digital opportunities and data science, energy, intelligent transportation, water resource management, and mining and minerals beneficiation.

World-class facilities

The Faculty's commitment to academic and research excellence is supported by facilities and equipment of the highest quality. Developments over the past five years that have contributed to enhancing the University's ability to train an increasing number of engineers to meet the critical national shortage of these important skills have included the Engineering 3 Building on the Hatfield Campus and the Mining Industry Study Centre at the entrance to the Engineering 1 Building.

An innovative new development is the Kumba Virtual Reality Centre for Mine Design, which was launched on 4 August 2015.

This centre in the Department of Mining Engineering will provide students with a realistic and immersive experience of the possibilities, limitations and challenges

→ *The Faculty attracts high-quality students and staff, and offers extended programmes to facilitate inclusiveness.*

of mine design; not only from a research perspective, but also in industry. It enables high-risk scenarios to be simulated in a safe and controlled environment where the consequences of any unsafe act can be powerfully demonstrated without causing any actual loss of life or damage to property.

A number of state-of-the-art laboratories and other research and training facilities are housed in the Engineering 1, 2 and 3 buildings and at other locations in close proximity to the lecture halls of the Faculty's programmes in engineering, built environment and information technology.

These include the Centre for Electromagnetism, the Institute of Applied Materials, the Carl and Emily Fuchs Institute for Microelectronics, and the Geotechnical Centrifuge Laboratory in the Department of Civil Engineering.

Meeting the challenges of a knowledge economy

According to Prof Sunil Maharaj, Dean of the Faculty of Engineering, Built Environment and Information Technology, the Faculty is in a strong position nationally, and is making a distinct impact in the country, not just in terms of human capital development, but also in the type of projects in which it is involved.

For example, researchers in the Department of Chemical Engineering are developing a fast pyrolysis unit that will be able to produce fuel from agriculture and forestry waste (see article on page 9), while in a project initiated in the Department of Civil Engineering, the Faculty was instrumental in launching South Africa's first small conduit hydropower facility in Bloemfontein (see article on page 59).

Industry partnerships

The Faculty's research agenda must continuously address the country's challenges and opportunities by strengthening partnerships with business and government.

This is illustrated by the signing of memoranda of understanding (MoUs) with various industry partners in support of training and research. Examples include an agreement signed with the CSIR for the establishment of a Chair in Aeronautics at the University of Pretoria in January 2015 (see article on page 27), a collaboration agreement signed with the Australian Institute of Building in April 2015 (see article on page 160), the establishment of the SARChI Chair in Advanced Sensor Networks in January 2015 (see article on page 33) and the launch of the South African Chapter of the Construction Industry Institute (CII) in May 2015 (see article on page 136).

As part of his vision for the Faculty, Prof Maharaj has identified the need to continuously attract and retain the top performers in our schooling system from across the country, as well as to attract and encourage more students to pursue postgraduate studies. This is vital if we are to take South Africa further into the knowledge economy.

Welcome to the Dean of Engineering, Built Environment and Information Technology

Prof Sunil Maharaj, the University's former Head of the Department of Electrical, Electronic and Computer Engineering and Chairholder of the Sentech Chair in Broadband Wireless Multimedia Communications (BWMC), was appointed to the position of Dean of the Faculty of Engineering, Built Environment and Information Technology at the University on 1 October 2014. This follows a research, industrial and academic career spanning more than 27 years.

With engineering and the associated disciplines in the School of Engineering within the Faculty of Engineering, Built Environment and Information Technology (EBIT) celebrating 60 years in 2016, Prof Maharaj is committed to building this Faculty on the great foundation that was established by his predecessors in order to make a distinct contribution to and impact on our great country and the African continent in terms of its economic competitiveness.

Academic background

Prof Maharaj obtained his BSc Engineering and MSc Engineering degrees in Electronic Engineering at the University of Natal in 1986 and 1989 respectively. He then completed an MSc in Operational Telecommunications with a merit pass from the University of Coventry in the United Kingdom in 1996. He returned to his alma mater to complete his PhD in Electronic Engineering in 2008.

He launched his career in Pretoria in 1989 at Electromagnetic Laboratories (EMLab) as a radio frequency (RF) and microwave design engineer. In 1992, he moved to academia when he accepted a position as senior lecturer at the Transkei Technikon. This was followed by his appointment as Director of the School of Engineering of the Eastern Cape Technikon in 1993, and Vice-Rector: Academic of the same institution a year later.

In 2000, Prof Maharaj joined the University of Pretoria as a senior lecturer, a position he held until 2008. During this time, he was appointed as the inaugural chairholder of the Sentech Chair in BWMC, a position he still holds. He became associate professor in the Department of Electrical, Electronic and Computer Engineering in 2009 and Acting Head of Department in 2011, and was promoted to Head of Department in 2012. In October 2014, he was appointed Dean of the Faculty for an initial term of four years.

Achievements

Prof Maharaj is a professional engineer (PrEng), fellow of the South African Institute of Electrical Engineers (SAIEE) and fellow of the South African Academy of Engineering (SAAE). He has published widely in several journals in his field, and has received recognition in the form of several awards, including the Technology and Human Resources for Industry Programme (THRIP) award of the Department of Trade and Industry (the dti) in the Advanced Hi-Tech Category for research work in broadband wireless communications in 2010, an award he received again in 2013.

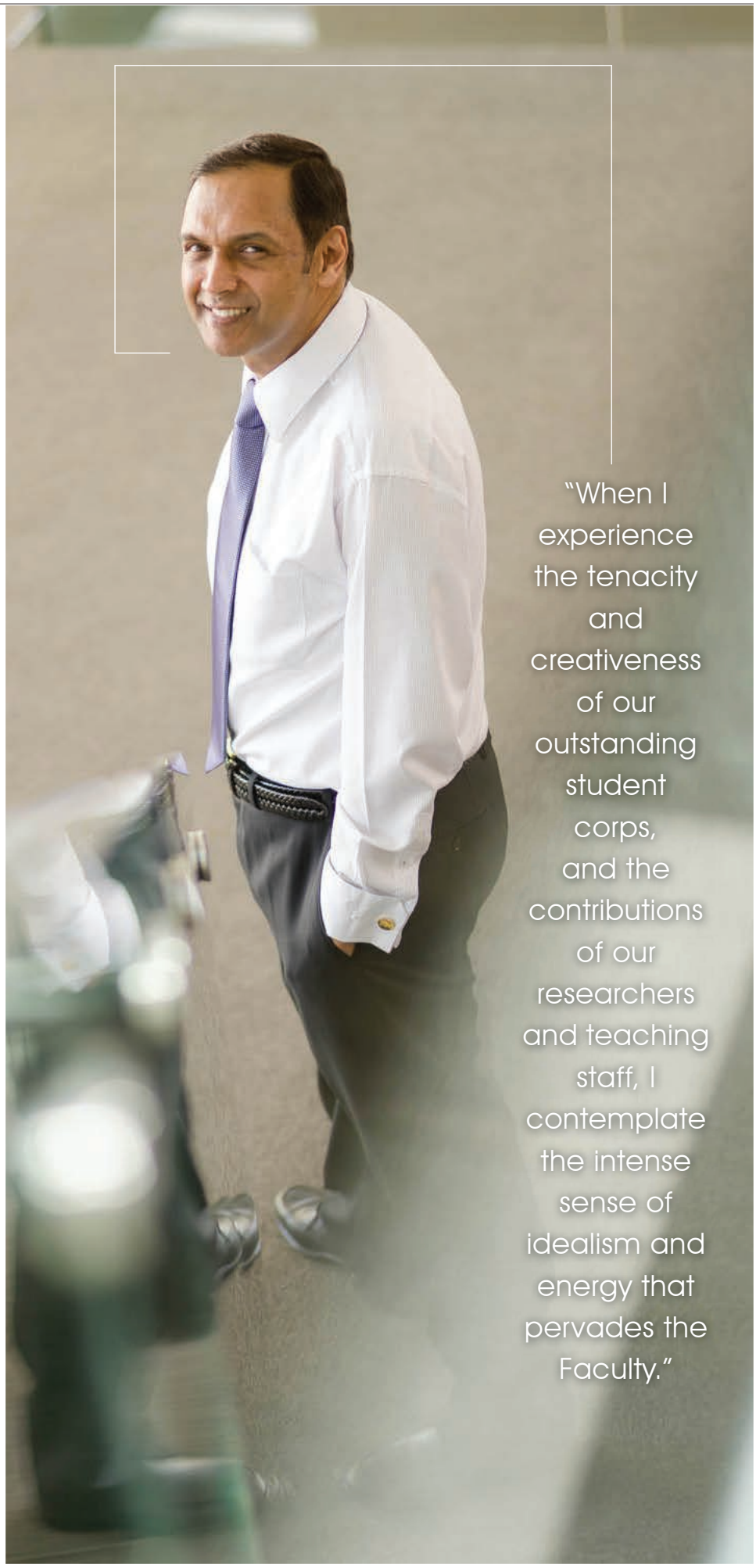
Prof Maharaj's vision for the Faculty is to build on the four pillars of quality, relevance, diversity and sustainability, as outlined in the University's strategic plan, *UP 2025*. In the process, he sees the Faculty contributing directly to the country's National Development Plan for 2030.

Looking back at his first year as dean, Prof Maharaj is filled with great optimism for the future. "When I experience the tenacity and creativeness of our outstanding student corps, and the contributions of our researchers and teaching staff, I contemplate the intense sense of idealism and energy that pervades the Faculty.

"I believe that each one of us has a unique opportunity and responsibility to meet the critical challenges of our time, and it is a privilege to be able to lead such an incredible Faculty at this time."

Prof Maharaj has articulated the following five-point plan, which contains the pertinent issues on which he intends to focus during his tenure as Dean:

- Enhancing the quality of the Faculty's programmes as required for professional and international accreditation, and the continuous improvement of its facilities so that UP can offer outstanding teaching and learning, as well as research opportunities to its graduates.
- Hiring, developing and growing talent so that the Faculty can develop a pipeline of outstanding future academics and researchers that are reflective of the country's diversity.
- Positioning the Faculty as a faculty of choice among learners, postgraduate students, parents and industry, so that it can attract and retain the top achievers, and be the preferred partner of industry in research and human capital development.
- Increasing international collaboration so as to strengthen UP's position in international research rankings.
- Improving and integrating the culture of technopreneurship, so that it can have a greater impact on society and industry competitiveness, and contribute to knowledge-economy-type job creation.



"When I experience the tenacity and creativeness of our outstanding student corps, and the contributions of our researchers and teaching staff, I contemplate the intense sense of idealism and energy that pervades the Faculty."

Research strengthens the Faculty's innovation capacity

Research is one of the core activities of the Faculty of Engineering, Built Environment and Information Technology at the University of Pretoria, and contributes to its positioning as one of the top faculties of its kind in the country. Several new research centres, institutes and units have been developed over the past few years to supplement the Faculty's vast research capacity. Some of these research entities and centres of excellence are featured in the following pages.

SARChI chairs

The South African Research Chairs Initiative (SARChI) forms part of the human and institutional capacity development programme of the National Research Foundation (NRF). Its main goal is to strengthen and improve the research and innovation capacity of public universities to produce high-quality postgraduate students, research and innovation outputs. The Faculty has been awarded four research chairs under SARChI.

SARChI Chair in Artificial Intelligence

The main research focus of this chair is computational intelligence, with a particular emphasis on computational swarm intelligence, learning from zero knowledge using competitive coevolution and evolutionary algorithms. The research team, under the leadership of A-rated researcher Prof Andries Engelbrecht, has developed an open-source library of computational intelligence algorithms, which is increasingly being used internationally.

SARChI Chair in Carbon Technology and Materials

The main research focus areas of this chair are nuclear graphite, the fabrication and characterisation of new carbon/graphite materials, composites and thermal materials, graphite oxidation and nano-carbon, with the emphasis on graphene research, which includes synthesis and characterisation, as well as applications to photovoltaic and energy storage as super capacitors and graphene/conducting polymer composites as gas sensors. This multidisciplinary research chair was awarded to the University of Pretoria in 2006, and is now in its second five-year term as part of SARChI.

SARChI Chair in Fluoro-materials Science and Process Integration

This chair was established in 2007 and has been functioning in the Institute of Applied Materials since 2010. Current research includes the development of a fluoro-polymer capability in South Africa. The focus is on polytetrafluoroethylene (PTFE), polyvinylidene fluoride (PVDF), fluorinated ethylene propylene (FEP) and pulverised fuel ash (PFA). Other focus areas include the dry fluorination of inorganic materials, the modelling of fluorine electrolysis cells and various projects of interest to the Advanced Metals Initiative (AMI) relating to fluoride-based minerals processing, and high-temperature processes for the production of high-value products directly from fluorspar.

The Faculty has been awarded four SARChI chairs.

SARChI Chair in Advanced Sensor Networks

The main research focus of this chair, established in January 2015, is building research capacity in the area of advanced sensor networks, a modern and growing field, which is strategic to the economy. The first five years of the programme will target research on the mathematical aspects of wireless sensor networks (WSN), while the subsequent five-year programme will focus on hardware, test beds and implementation aspects. The applications to be considered will have major national interest, especially in the wildlife monitoring, soil and in-situ soil moisture analysis (for viticulture), home security, the monitoring of health infrastructure and human healthcare. (See article on page 33.)

The SARChI Chair in Carbon Technology and Materials focuses on nuclear graphite, as well as the fabrication and characterisation of new carbon/graphite materials.

Industry-sponsored chairs

Support from industry enables the University to conduct cutting-edge research in specific fields, while providing postgraduate students the opportunity to be mentored by established researchers who are at the forefront of their research areas.

Electrical, electronic and computer engineering

In addition to the SARChI Chair in Advanced Sensor Networks and the Sentech Chair in Broadband Wireless Communications (featured in this issue), there are a number of other chairs in the Department of Electrical, Electronic and Computer Engineering that conduct research on a variety of aspects in this field, including power electronics, electronic defence research, microelectronics, electromagnetism, and telecommunications engineering for the information society.

CBI-electric: Low Voltage Chair in Power Electronics

The CBI-electric: Low Voltage Chair in Power Electronics was launched in the Department in 2012. The chair is funded by CBI-electric: Low Voltage (previously known as Circuit Breaker Industries). It will initially support salaries, undergraduate and postgraduate bursaries and research project costs in the Department for a period of three years. Furthermore, CBI-electric: Low Voltage has sponsored power electronics and electrical equipment to the value of R140 000, which students will use for their design project work. It is envisaged that this partnership with CBI-electric will lead to further research and product development, as well as human capital development.

Chair in Electronic Defence Research

The Chair in Electronic Defence Research was established with the support of the Council for Scientific and Industrial Research (CSIR) and undertakes research related to exploiting the electromagnetic spectrum to the maximum benefit of oneself and one's allies, and to the maximum detriment of one's adversaries. As such, it exploits all specialist fields within the general scope

→ *Prof Monuko du Plessis of the Carl and Emily Fuchs Institute for Microelectronics was nominated for the prestigious NSTF-BHB Billiton Awards for his work in 2015.*

of electrical, electronic and computer engineering. Current research topics include cross-eye jamming, automatic electronic warfare mission planning, sub-Nyquist sampling and low-cost training systems. Four webinars have been presented under the auspices of the Association of Old Crows (AOC), a major international association that focuses on electronic warfare and related fields. Furthermore, an international university has approached UP for information on establishing similar programmes there.

Carl and Emily Fuchs Institute for Microelectronics

The Carl and Emily Fuchs Institute for Microelectronics (CEFIM) has been active in the field of microelectronics research and specialist training since 1981.

The research and postgraduate programme mainly covers integrated circuit design, especially the design of analogue signal processors, radio frequency circuits and optical receivers in complementary metal-oxide-semiconductor (CMOS) technology. The application of semiconductors as opto-electronic devices plays an important role in the institute's activities.

The injection-enhanced silicon in avalanche (INSiAVA) technology, which has been successfully commercialised by the University of Pretoria, was developed by a team led by CEFIM's Prof Monuko du Plessis. Prof Du Plessis was nominated for the prestigious National Science and Technology Forum and Broken Hill Proprietary (NSTF-BHP) Billiton Awards for his work in 2015.

Centre for Electromagnetism

The Centre for Electromagnetism has comprehensive measurement facilities, and this research group, comprising a team of three researchers, has developed very strong computational abilities in various aspects of electromagnetism. The research of this centre is focused on achieving a high level of excellence in electromagnetic technology, particularly in the design, development and evaluation of microwave antennae, radar backscatter and antenna measurements. Various novel antenna-radiating elements have been developed, as well as feeding and matching techniques with specific application in wireless and array technology. The Director of the Centre, Prof Wimpie Odendaal, has contributed to the practical implementation of polarisation optimisation for conformal antenna arrays.

Centre for Telecommunications Engineering in an Information Society

The Centre for Telecommunications Engineering in an Information Society (CeTEIS) brings together a team of researchers from electronic engineering and computer science. It was established in 1997 with the support of Telkom, but also receives support from

other industry partners. Its research focuses on realising the vision of a totally connected planet, in which humans and machines are seamlessly interconnected, and where new applications, such as Smart City applications, become a reality for a better living. The Centre has been awarded a Technology and Human Resources for Industry Programme (THRIP) grant for a project entitled FutureCloud, which considers the unification of cloud computing, cloud communication and technology convergence, moving towards a future internet network.

Maintenance engineering and asset integrity management

The Centre for Asset Integrity Management (C-AIM) in the Department of Mechanical and Aeronautical Engineering was established in 2014 as a result of the cumulative growth of knowledge and expertise in asset management conducted in a number of research chairs and institutes in the Department. It benefits from long-term industry partnerships with companies like Eskom, Exxaro, Weir Minerals and Rand Water.

The Centre developed from a Centre of Excellence in Maintenance Engineering that was established in 2008 with industry support from Sasol, Eskom, Exxaro and Anglo American. The Centre was established to conduct research on aspects such as structural fatigue testing, experimental modal analysis and vibration modelling. In 2012, Eskom established a Specialist Centre for Plant Asset Management as part of the Eskom Power Plant Engineering Institute (EPPEI) initiative, with a research focus on asset integrity management. This was followed by the establishment in 2014 of the Rand Water Chair in Mechanical Engineering, as well as a collaboration agreement with Weir Minerals to establish a research focus on machine condition monitoring.

The consolidation of the activities of these research chairs and institutes into a single centre has created a very interesting research environment in which highly technical issues pertaining to structural and machine failures and remaining useful life are integrated into well-founded management decisions.

Energy research

The University has for some years recognised the need to conduct focused research in the field of energy in an effort to address the energy crisis that is facing South Africa. It has therefore established a number of strong multidisciplinary research groups led by acknowledged international leaders, as well as industry-sponsored chairs. Research is conducted across a number of departments, including Electrical, Electronic and Computer Engineering, Mechanical and Aeronautical Engineering, Chemical Engineering, and Engineering and Technology Management, as well as in the Institute for Technological Innovation.

FutureCloud, a project of CeTEIS, considers the unification of cloud computing, cloud communi-cation and technology convergence, moving towards a future internet network.

National Hub for Postgraduate Programme in Energy Efficiency and Demand-side Management

The South African National Energy Development Institute (SANEDI) selected the University of Pretoria to house the Energy Efficiency and Demand-side Management (EEDSM) Hub. SANEDI, a subsidiary of CEF (Pty) Ltd, is a joint initiative of the Department of Science and Technology and the Department of Energy. SANEDI identifies energy efficiency and demand-side management as key research and development themes for South Africa. The EEDSM five-year postgraduate programme was initiated as one of the targeted, government-funded programmes to generate high-quality master's and doctoral graduates who are specifically trained to meet the needs of an expanding and sustainable energy industry in South Africa.

Centre of New Energy Systems

The Centre of New Energy Systems (CNES) is a research centre in the Department of Electrical, Electronic and Computer Engineering. It has gained a reputation as a premier research institute in the area of energy management, both nationally and internationally. It is the only Centre of Excellence in energy optimisation and standardisation in South Africa to address the research, education, development and industrial applications of energy optimisation and management. The focus on energy management

includes both supply-side and demand-side management. It collaborates with research centres on energy management both locally and internationally.

Exxaro Chair in Energy Efficiency

This chair was established in June 2012 with the industry support of Exxaro. It is hosted by the Centre of New Energy Systems. The mission of this chair is to participate in forefront research activities in the field of energy efficiency and to deliver world-class research and educational outputs for the benefits of Exxaro, the University of Pretoria, and South Africa in general. This chair is specifically devoted to addressing energy-efficiency problems of industrial processes by modelling, optimisation, control and management techniques. The chair also aims to train suitably qualified engineers to solve practical engineering problems and work for the industry.

Institute for Technological Innovation

The research of the Institute for Technological Innovation (ITI) is focused on quantitative studies of science, technology and innovation policy, including assessments, international benchmarking and scientometrics. The ITI is particularly interested in multidisciplinary fields like energy and water. The ITI's research has been informing and initiating a number of policy actions in the country. Examples include the introduction of tax incentives for research and development in the country, the linking of financial support to researchers who are rated by the NRF and the current recommendation in the draft intellectual property policy for the introduction of an examining approach in the country's patent system.

Clean Energy Research Group

The Department of Mechanical and Aeronautical Engineering has been active in research on energy systems – including thermoflow systems – since the early 1980s. Research areas originally focused on heating, ventilation, and air-conditioning (HVAC) systems and engines. Since the early 1990s, there has been a growing emphasis on computational research in the thermoflow field, with applications like electronics cooling and industrial computational fluid dynamics (CFD) gaining ground. These activities are currently balanced by a growing group in experimental heat transfer and CFD research. The applications of these research areas have been consolidated into a broader focus on clean energy systems and components. The research of the Clean Energy Research Group is currently focused on energy systems, renewable energy (solar, fuel cells, wind and ocean

Centre of Excellence for Nuclear and Radiation Safety

The National Nuclear Regulator (NNR) has taken the initiative to establish a Centre of Excellence for Nuclear and Radiation Safety at the University of Pretoria. This is mainly motivated by government's envisaged nuclear expansion programme. One of the important questions that the NNR and government will have to answer is: "Is the NNR ready and does it have the necessary infrastructure and resources to regulate all the future use of nuclear technology in South Africa. On 20 February 2015, a one-day workshop was held on the Hatfield Campus as an initial interaction to verify the University's capabilities to host such a Centre of Excellence. The workshop was attended by the heads of various departments and other researchers. Prof Stephanie Burton, Vice-Principal: Research and Postgraduate Studies, and Prof Sunil Maharaj, Dean of the Faculty of Engineering, Built Environment and Information Technology, welcomed the delegation and presented the achievements and growth statistics of the University. The University's other delegates then presented their departments' individual capabilities. The day was concluded by a visit to the various laboratories, with specific attention being paid to those that could potentially be of interest to the NNR.

The NNR plans to select and appoint the host partner institution and to appoint the Director of the NNR Centre for Nuclear Safety and Security (CNSS) by the end of November 2015.

engineering), nuclear energy, energy efficiency and optimisation, heat exchangers, nanofluids, gas turbines and aerodynamics.

Water resource management

Research into water resource management is a focus area of both the Department of Chemical Engineering and the Department of Civil Engineering. The Water Utilisation and Environmental Engineering Division in the Department of Chemical Engineering is supported in its research activities by the Sedibeng Water Research Chair in Water Utilisation Engineering (featured in this issue), while the Department of Civil Engineering enjoys the support of Rand Water for research into water purification, supply and utilisation-related science and engineering.

Rand Water Chair in Civil Engineering

This research chair was established in the Department of Civil Engineering in 2014, and is engaged in research on determining a change in the hydraulic capacity of pipelines.

This research, under the leadership of Prof Fanie van Vuuren, examined the elements to be considered in the hydraulic design of pipelines. The research team considered the recorded hydraulic performance of pipelines, secondary energy loss associated with the dimensional details of the couplings, the adaption of the friction formula to include the influence of biofilm growth, and the provision of monitoring points for the continuous or intermittent hydraulic assessment of the pipeline.

The research found it to be imperative that a periodic review of the hydraulic performance of conveyance systems be undertaken, which would be simplified if the design of water systems included sufficient access points on the system to measure flow and pressure.

Chemical engineering

The Department of Chemical Engineering is active in a number of specialist research fields. These include the activities of the Environmental Engineering Group (see articles on pages 125–132), the Sedibeng Water Research Chair in Water Utilisation Engineering, the SARChI Chair in Carbon Technology and Materials, the SARChI Chair in Fluoro-materials Science and Process Integration and the Institute of Applied Materials (IAM).

The IAM performs applied research for the industry. It pursues research and development targets in carbon materials and chemical product design, including modelling multicomponent mixture properties, layered solids as functional additives for polymers, green pyrotechnics and combatting malaria transmission.

Innovative research into water security receives award

Marco van Dijk of the University's Department of Civil Engineering, who has conducted groundbreaking work in the development of South Africa's first conduit hydropower facility (see article on page 59), has been recognised by the Water Research Commission (WRC).

On 17 September 2015, Van Dijk received the prestigious Knowledge Tree Award in the category New Products and Services for Economic Development. The award was made in recognition of the impact of his research, as well as his significant contribution to water science and technology.

Water is essential for local development, particularly for sectors such as health, agriculture, economic development, education and the environment. However, 768 million people in the world do not have access to clean drinking water.

Van Dijk's research is closely aligned to the post-2015 Agenda, in which integrating universal access to drinking water and basic sanitation is a priority for the water and sanitation sector worldwide. His particular research interests include hydropower development for rural electrification in South Africa, energy generation using low-head hydropower technologies, and conduit hydropower implementation. He has compiled numerous technical reports and journal articles in the field of pipelines, hydropower generation and water distribution systems.

Dr Limakatso Moorosi, Chief Executive of Bloemwater (left), Mr Marco van Dijk (centre) and Mr Dhesigen Naidoo, CEO of the Water Research Commission.

Taking aeronautics to new heights

Aerospace or aeronautics is a field in which qualified graduates can play an important role in increasing the global competitiveness of the industry. By engaging in applied research at postgraduate level under the guidance of skilled professionals with industry experience, a new generation of aeronautical engineers will ensure that South Africa is recognised as a leader in this highly specialised field.

The University of Pretoria is the only tertiary institution in South Africa to offer a postgraduate qualification in aeronautical engineering. Until now, research in this field has been very limited, with most of the applied research in the country being conducted by institutions such as the Council for Scientific and Industrial Research (CSIR), specifically its Aeronautic Systems Research Group. Industry specialists are also found in but a few niche aerospace and defence organisations, such as Denel Aerostructures, Paramount Advanced Technologies (PAT) and Incomar Aerospace and Defence Systems (IADS).

Qualified aeronautical engineers, however, remain in short supply, especially graduates with a thorough understanding of the industry in which they are to forge a career for themselves. In an effort to address this challenge, the University of Pretoria has collaborated with the CSIR to establish a Chair in Aeronautics in the Department of Mechanical and Aeronautical Engineering. This Chair will not only enable more research to be conducted in this field, but will ensure that the aeronautical engineers that are delivered to the industry are equipped to deal with the challenges they will face.

This Chair was established in an effort to assure industry partners that aeronautical engineers who have graduated with a postgraduate qualification in mechanical and aeronautical engineering from the University of Pretoria are suitably qualified for the specialised aerospace and defence industry. It will also increase the University's capacity in this field, and ensure that academic programmes and research projects are designed to meet industry needs.

The inaugural Chairholder is Prof Laurent Dala, Research and Development Leader of the CSIR's Aeronautic Systems Research Group. Prof Dala has more than 25 years' experience in aeronautical/aerospace engineering, having worked at research centres and universities in France, Russia and England, as well as in industry (Airbus, CargoLifter and Ratier Figeac). He specialises in aerodynamics, flight dynamics, aeroelasticity, aeroacoustics and multi-design optimisation, and was involved in the undergraduate programme in aeronautical engineering at the University of the Witwatersrand.

According to Prof Dala, the Chair will develop and enhance applied research and create a strong synergy between the aerospace industry and academia. The Chair will strengthen research collaboration between the University and the CSIR, which will be beneficial to new research projects, as valuable knowledge can be exchanged. It will also provide a platform for developing more scholars in this discipline.

Qualified aeronautical engineers are in short supply.

In addition to research, the Chair will contribute to the development of postgraduate study programmes in the Department. "We anticipate that academic programmes will evolve with industry," says Prof Dala. In collaboration with Prof Josua Meyer, Head of the Department of Mechanical and Aeronautical Engineering, Prof Dala is collaborating with industry role-players to develop the Department's first master's degree in aeronautical engineering – and also the first such degree in South Africa. It will be presented from the 2016 academic year.

Prof Laurent Dala, Chairholder of the CSIR-UP Chair in Aeronautics.

Topics to be covered include aeroelasticity, avionics, advanced aerodynamics, aircraft structure, aircraft propulsion, missile aerodynamics and design, flight dynamics, unmanned air system technology and experimental methods.

Lectures will be presented by specialists from the CSIR, PAT, Denel Aerostructures and IADS, who will also supervise students' research projects.

With the launch of this research chair, together with the postgraduate study programme, the Department of Mechanical and Aeronautical Engineering looks forward to becoming part of an exciting new chapter in South African aeronautics, and hopes to maintain its close links with industry in support of teaching and research excellence.

International Council of the Aeronautical Sciences Congress

Prof Laurent Dala, Chairholder of the CSIR-UP Chair in Aeronautics, and Dr Bennie Broughton of Incomar Aerospace and Defence Systems (IADS) had the privilege of having two of the master's students in mechanical and aeronautical engineering that they had supervised present papers at the 29th Congress of the International Council of the Aeronautical Sciences (ICAS) that took place in St Petersburg, Russia, from 7 to 12 September 2014.

Some 867 participants from 43 countries attended the congress, and more than 550 papers were published in the proceedings document. Guests of honour at the official opening ceremony included Mr Vladimir Kargopoltsev, Director of the United Aircraft Corporation, and Dr Andrey Maximov, Chairman of the St Petersburg Government Committee for Science and Higher Education. Delegates were also treated to a special video message from the crew of the International Space Station.

Several prizes were awarded at a gala banquet at the end of conference. The South African students made ICAS history when Prof Dala's student, Marius-Corné Meijer (who had received his degree from the University of the Witwatersrand), received first prize for the best student paper, while Dr Broughton's student, Elizna Miles (who had received her degree from the University of Pretoria), was awarded the runner-up prize. Not only was this the first time that both the winner and runner-up of this competition hailed from the same country, but they were the only master's degree students to compete against an international field of PhD candidates.

Meijer's paper outlined the development of a zero-order aeroelastic prediction method for plate-like structures in supersonic flows, while Miles's paper presented an overview of the work conducted as part of the design of a control system for a miniature unmanned aerial vehicle (UAV) with a rhomboid wing configuration.

Digital, experimental and econometric initiatives contribute to an enabling transportation sector

The transportation sector is a key contributor to South Africa's competitiveness in global markets, and is regarded as a crucial engine for economic growth and social development. Researchers in the Department of Civil Engineering, in collaboration with colleagues in other departments at the University, are launching a multi-pronged initiative to ensure that the country's road infrastructure can compete with the best in the world.

The focus of the Department's research is on both the durability of the materials used in the construction of the road pavement, and the intelligent planning of the transportation infrastructure. By analysing the pavement structure on the basis of the type and quantity of traffic it is expected to carry in its lifetime, civil engineers are able to determine the best design for each class of road in the national and local road network.

However, the dynamics of the transportation industry entails more than just the carrying capacity and performance of the road pavement. The behavioural patterns of commuters and other road users have a major impact on traffic, and for this reason, strategic transportation planning has an indispensable role to play in developing an enabling transportation sector.

Pavement engineering

The Department's expertise in pavement engineering resides primarily in the specialised experience of Prof Wynand Steyn and Prof James Maina. Prof Steyn has a special interest in vehicle-pavement interaction, accelerated pavement testing and pavement materials and instrumentation. He spent 19 years with the Council for Scientific and Industrial Research (CSIR) in various technical and managerial positions before joining the University. Prof Maina, who joined the University in October 2014, was a chief research engineer and leader of the Pavement Design and Construction Group at CSIR Built Environment. He spent close on ten years with the CSIR, of which 18 months were on a sabbatical in Qatar.

While at the CSIR, Prof Maina developed numerical modelling tools, system identification, software and parallel processing protocols focusing on pavement engineering applications. In Qatar, he was responsible for developing quality management systems for quality assurance and quality control in road design and construction projects in preparation for Qatar's hosting of the 2022 FIFA World Cup.

At UP, Prof Maina continues research in the same areas, while building the skills and capacity of students in the Department of Civil Engineering.

The work of the pavement engineering team focuses on both the physical qualities of the road pavement and modelling to predict the performance of a particular pavement type by using properties of the different materials that are used.

To support the experimental findings, the University has recently started to make use of simulation-based research, which makes use of numerical tools to predict the performance of the road pavement. This process is expected to lead to very cost-effective pavement design solutions for South African roads.

Transportation engineering

Strategic transportation planning is of vital importance when it comes to accommodating the needs of commuters and other road users, and their impact on traffic.

The Department's expertise in this field resides in the experience of Prof Christo Venter. Prof Venter has an interest in transportation planning, land-use and transport interactions, travel behaviour research and modelling, and public transportation planning and operations.

According to Prof Venter, researchers at the University of Pretoria are investigating a number of related topics that will contribute to a better user experience in terms of road travel. These include the statistical analysis of travel data and the development of cost-effective modelling methods for transport planning in developing countries, as well as the use of new technologies in travel data collection, such as GPS data and crowdsourcing.

A convoy of trucks transporting freight head south down the N1 highway, just outside Polokwane. Photo: Graeme Williams, MediaClubSouthAfrica.com.

Research has also been conducted on the interaction between transport systems and land use, social equity, quality of life and the economy. This includes aspects such as the impact of gated communities on travel and mobility, the impact of public transport innovation (like the deployment of the Bus Rapid Transit system) on urban poverty, and accessibility as a means of measuring the impact of transportation. A number of these research projects are conducted in the Centre of Transport Development.

Centre of Transport Development

The Centre of Transport Development is a collaborative research entity in the School of Engineering that pursues multidisciplinary research in the areas of rail, pavement engineering, transport planning and operations, and mobility modelling.

The Centre was initially established with the support of the national Department of Transport, and several collaborative projects have been undertaken by researchers from the Department of Civil Engineering and the Department of Industrial and Systems Engineering.

Other departments that have also been included in research projects are the Department of Town and Regional Planning and the Department of Economics in the Faculty of Economic and Management Sciences.

Prof Johan W Joubert of the Department of Industrial and Systems Engineering has a particular interest in the modelling, simulation and optimisation of transportation systems, and as such, has been involved in projects that make use of transport modelling to support infrastructure investment and policy evaluation.

According to Prof Joubert, the increasing digitisation of transportation systems opens up the potential of using GPS data, as well as data captured on the E-Toll gantries, to optimise transportation planning. Future research projects in the Centre of Transport Development will be able to exploit this data-rich environment to analyse, monitor and manage movement on the roads by tracking the movement of vehicles and freight in order to anticipate the future needs of road users.

By means of simulation-based studies, the behaviour and movement patterns of private commuters, minibus taxis and freight vehicles can be anticipated and predictions made that will assist in the planning of road networks.

This research will make an important contribution to infrastructure development, while improving the flow of traffic.

Railway engineering is on track for the future

The Transnet Chair in Railway Engineering in the Department of Civil Engineering was established 23 years ago when Spoornet (now Transnet Freight Rail) initiated a partnership between industry and the University. This partnership revolves around three major activities: graduate training, continuing industry-oriented education and railway research.

The Chair places a strong focus on track infrastructure research and is very active in the fields of conventional ballasted and unconventional track structure performance, track maintenance models, maintenance limits and condition monitoring, stress and strain measurement systems, asset management, and maintenance management strategies and philosophies. It is also actively involved in the development of non-destructive track condition monitoring technologies such as ground-penetrating radar.

The importance of rail transport in South Africa has never been more prominent than in recent years. This was confirmed in March 2015 when government announced its intention to invest more than R300 billion over the next three years in an effort to reduce road deaths and traffic congestion, while also expanding the country's cargo transport capabilities. The vast majority of this investment will go towards upgrading and expanding the national rail network.

According to a statement made by Mr Malusi Gigaba, Minister of Public Enterprises, the planned infrastructure projects for this sector will not only relieve the burden on our roads, but will also significantly increase the country's export capacity, rejuvenate the economy, create jobs and address poverty and inequality.

Test track

Rail infrastructure is a critical part of any country's supply chain.

Rail infrastructure is a critical part of any country's supply chain, as it enables the efficient movement of large quantities of goods, while having a minimal impact on the people and communities it serves. Research has shown that transport by rail is three times more fuel efficient than conventional road transport, which means that gas emissions can be decreased significantly.

Efficient and effective freight rail transportation in South Africa will reduce the number of heavy transport vehicles that are currently using the road infrastructure, thereby improving safety on our roads and making South African commodities more affordable for consumers. Additional economic benefits that the country can look forward to once its new railway infrastructure is in place include lower expenditure associated with road maintenance, policing and accidents.

According to Prof Hannes Gräbe, Chairholder of the Transnet Chair in Railway Engineering, skills transfer, teaching and continued education are keys to unlocking the potential required to achieve short- and long-term goals in the rail industry, and investment in research and development will increase the competitive edge that transport by rail has over other modes of

Field testing at Amandelbult Station near Thabazimbi in Limpopo.

transport. He is convinced that researchers at the University or Pretoria, in collaboration with railway stakeholders, have the technical expertise and facilities needed to be a leader in railway engineering in Africa.

A proper understanding of railway infrastructure management is paramount in the railway engineering field, which makes the research being conducted by the Transnet Chair in Railway Engineering especially relevant in terms of the country's planned rail infrastructure projects. Investment in track infrastructure represents significant social, economic and environmental decisions, and is likely to have a major long-term impact on all three of these spheres.

The research being done at the University, along with the skills transferred to industry, will inform decision-making about the life cycle of rail infrastructure so as to avoid system failures that may lead to expensive production losses, which could also impact negatively on the environment and consumer safety.

Researchers in the Transnet Chair in Railway Engineering have access to two railway test tracks on the University's experimental farm. One is a 30-metre conventional railway track section, while the other, a more recent addition to the University's research facilities, is an 18-metre Tubular Modular Track section. The track structures conform to heavy-haul track structure design requirements and are ideal for full-scale stress and strain tests in a controlled environment, testing the effect of moisture on the strength of the track foundation under load conditions, evaluating earthworks specifications under load conditions and under different moisture conditions, and evaluating different foundation characterisation methodologies and equipment. The researchers are also well equipped to conduct standard laboratory tests on various track components as they have access to a range of tests and laboratory experiments that can be conducted in the laboratories of the Department of Civil Engineering. These tests include standard sleeper-bending tests to the specifications of the American Railway Engineering and Maintenance-of-Way Association (AREMA) or any other standard specification, full-scale tests on sleeper components, such as rails, sleepers, pads and ballast, static and dynamic fatigue tests, the testing of slab track components, the testing of under-sleeper pads (USPs), and special non-standard tests designed and configured in accordance with client requests.

At a recent function held to celebrate the Chair's 23-year relationship with Transnet, the Dean of the Faculty of Engineering, Built Environment and Information Technology, Prof Sunil Maharaj, mentioned that the University's relationship with Transnet is a sterling example of how academia and industry partners can work together to meet the greater needs of society. He said that the Faculty's strength lies in forging relationships with industries and serving them by offering globally competitive courses.

SARChI Chair in Advanced Sensor Networks

→ *Prof Gerhard Hancke, Head of the Advanced Sensor Networks Group (left), Prof Attahiru Alfa, incumbent of the SARChI Chair in Advanced Sensor Networks, and Prof Sunil Maharaj, Dean of the Faculty of Engineering, Built Environment and Information Technology (right).*

Due to its standing in the local and international research community, the Advanced Sensor Networks (ASN) Group in the Department of Electrical, Electronic and Computer Engineering was awarded a Research Chair in ASN under the South African Research Chairs Initiative (SARChI).

The research chair is co-hosted by the Department's ASN Group and the Meraka Institute at the Council of Scientific and Industrial Research (CSIR) under the digital@SERA partnership.

The ASN Group is a leading hub of research and development in the field of ASN. It was established in 2005 by Prof Gerhard Hancke, and aims to be a focal point in the creation of a critical mass in this key field, partnering with local and overseas academic institutions, research organisations and industry.

The application of ASN technology can result in intelligent environments that are able to monitor themselves and take proactive steps without human intervention. ASN refers to the set of technologies and disciplines that allow distributed embedded systems to cooperatively sense, decide, learn and act in real-time to achieve certain goals. This can revolutionise our understanding and control of the physical world. This field has a vast and diverse application potential, which spans spheres such as manufacturing, agriculture, the natural environment, the built environment, security, the military and medicine.

The SARChI Chair, which was officially launched on 1 January 2015, will form a vital part of the activities of the ASN Group. It is headed by Prof Attahiru Alfa, a professor of tele-communication systems in the Department of Electrical and Computer Engineering at the University of Manitoba, Canada, who will make a significant contribution to the research outputs of the Department of Electrical, Electronic and Computer Engineering at the University of Pretoria.

The focus of this research programme is building research capacity in the area of ASN. The first five years of the programme will target research on the mathematical aspects of wireless sensor networks (WSN), while the subsequent five-year programme will focus on hardware, test beds and implementation aspects.

The applications to be considered will have major national interest, especially in wildlife monitoring, soil and in-situ soil moisture analysis (for viticulture), home security, infrastructure health monitoring and human healthcare.

Researching wireless broadband technologies

CHAIR in Broadband Wireless Multimedia Communications

The Sentech Chair in Broadband Wireless Multimedia Communications (BWMC), hosted in the Department of Electrical, Electronic and Computer Engineering, was formally established in 2005 with the support of Sentech.

Its primary objective is to promote research into wireless broadband technologies and their practical applications in a developing country. It participates in state-of-the-art research activities, and delivers world-class research and educational outputs for the benefit of its sponsor, the University of Pretoria and South Africa in general.

Since its official inauguration in 2006, the Chair has operated under the leadership of Prof Sunil Maharaj, Dean of the Faculty of Engineering, Built Environment and Information Technology. Among other things, it aims to promote research in the field of BWMC, collaborate on Sentech's related products, develop high-quality technical skills and expertise for industry and the research fraternity, and contribute to the global competitiveness of Africa and South Africa.

Research is focused on multiple-input and multiple-output (MIMO) systems with orthogonal frequency division multiplexing (OFDM) technology in wireless communication systems and cognitive radio technology. In 2013, collaborative work conducted by the BWMC research group earned Prof Maharaj a Technology and Human Resources for Industry Programme (THRIP) Award in the Advanced Hi-Tech Research category. The interdisciplinary nature of this research requires a wide range of skills.

Ms Leago Takalani, Executive: Technology of Sentech (left) joins Prof Sunil Maharaj, Dean of the Faculty of Engineering, Built Environment and Information Technology, in celebrating the renewal of Sentech's support of the Chair in Broadband Multimedia Wireless Communications.

The initiative enhances collaboration between different skills bases.

The initiative therefore enhances collaboration between different skills bases and creates an environment that will teach people to communicate, adapt and work in a multicultural environment.

In recognition of a decade of research excellence, Sentech has allocated funding for another four-year term for the research group to continue its innovative work in this globally relevant field.

Sedibeng Water Chair in Water Utilisation Engineering

CHAIR in Water Utilisation Engineering

The Sedibeng Water Research Chair in Water Utilisation Engineering was launched in the University of Pretoria's Department of Chemical Engineering in the Faculty of Engineering, Built Environment and Information Technology on 9 September 2014.

From left to right: Prof Roelf Sandenbergh, former Dean of the Faculty of Engineering, Built Environment and Information Technology, Prof Evans Chirwa, Chairholder of the Sedibeng Water Research Chair in Water Utilisation Engineering, Mr RT Takalane, Chief Executive of Sedibeng Water, and Prof Philip de Vaal, Head of the Department of Chemical Engineering at the University of Pretoria.

This research chair, with Prof Evans Chirwa as Chairholder, will focus on the delivery of high-quality water, and follows an integrated approach to total water management via ongoing participation in research activities and promoting consumer awareness of the value of water. The Department's broad objectives are to promote research in the South African water sector and the training of water engineers. The focus is on controlling the growth of algae, odour-causing and toxic organic compounds and the optimisation of chlorine doses to meet demand.

The research chair's first round of funding will last for five years with an annual budget of R1.4 million. The funding will be used to build capacity and support research in the remediation of algal infestation and the impact of eutrophication on natural water bodies. The research will focus on controlling algal growth, determining carbon cycling and improving the treatability of algal metabolites in the interim.

It is well known that algal metabolites are responsible for the foul odour and taste in water from natural water bodies with high nutrient loading. Additionally, the treatment of algae-infested waters with chlorine produces a range of disinfection byproducts (DBPs), including trihalomethanes (THMs) and haloacetic acids (HAAs). THMs and HAAs are suspected carcinogens and their occurrence at high concentrations is of great concern to water supply service providers. The soup of organics that is recycled in the water body from dead algal cells in the sediment zone of a reservoir creates a high chlorine demand during the water treatment. This means that the initial dose of chlorine is consumed by the organics and is therefore not available as an effective disinfectant to disease-causing bacteria in the water.

Apart from addressing some of the problems encountered at Sedibeng Water, the research supported by the Chair will also address problems encountered at other treatment plants, since algal problems are encountered globally. Problems associated with the algal infestation of water bodies and the resultant diminishing water quality are mainly products of increased agricultural and industrial activities that contribute the largest portion of nutrient loading to water bodies.

Research in mineral sciences contributes to the country's wealth

One of the key research areas identified in the Faculty to address national, regional and global challenges is research into mining and minerals beneficiation. Two departments that conduct complementary research in the mineral sciences supply chain are Mining Engineering (related to the extraction and exploitation of the country's mineral reserves) and Materials Science and Metallurgical Engineering (related to processing and refining mineral resources into viable materials, and the performance of the materials in service).

Mining Engineering

Research focus areas that receive particular attention in the Department of Mining Engineering include those of rock mechanics and underground mine design, rock breaking and surface mining, mine management and leadership, mine ventilation engineering, risk management, mineral economics, and underground mining methods and mine design. With the support of industry, the Department has established two research chairs, as well as an innovative research institute, to conduct research into some of the pertinent issues facing the mining industry both in South Africa and internationally.

Harmony Chair in Rock Engineering and Numerical Modelling

Mining at depth or mining highly stressed areas commonly occur in the South African gold mining industry due to the age of operations and the extent of mining conducted over the last century. The safety concerns related to mining these areas, especially in terms of seismic activity, have the potential to limit future gold production, unless methods are found to select and manage mining within acceptable risk levels.

The Harmony Chair in Rock Engineering and Numerical Modelling conducts research into rock engineering, and specifically the impact of mining sequences and mining rate on seismic activity in deep-level mines or highly stressed areas such as remnants or shaft pillars. This research will initially focus on seismic and mining-related parameters that have historically been used to measure the risk involved in mining these areas. It will ultimately search for more appropriate parameters, and even methods of determining these parameters.

This will include the use of numerical modelling packages and the potential to develop a constitutive law that could simulate strain softening, or a stress drop in areas where stress fracturing has occurred, normally ahead of the mining faces. The potential constitutive law could allow for the dissipation of a portion of the energy available to generate seismic activity within the model, and could assist in the comparison of different mining sequences to decide on the lowest risk option for implementation.

Research outcomes will be applied to specific sites for mines for which sufficient seismic data exists, in an attempt to correlate results or at least indicate the applicability of the findings to date. Research will be conducted by external rock engineering practitioners within the industry as part of their individual postgraduate study programmes, with the help of postgraduate students at UP and under the leadership of Prof Francois Malan and Prof John Napier. The research outcomes not only have the potential to affect the safety of deep-level mine workers, but will also be used to expose undergraduate and postgraduate students to the potential impact on the safety and profitability of well-designed and well-managed mining practices.

At the same time, the value of a team approach in mining is emphasised, where the mine manager should use all the skills available to him (in this case, high-level rock engineering skills) to facilitate safe and profitable mining practices.

Sasol Chair in Safety, Health and Environment

The Sasol Chair in Safety, Health and Environment aims to improve the health and safety performance of the mining industry, mainly through the Executive Certificate in Safety, Health, Environment and Community (SHEC) Resilience for managers in the mineral resources industry.

This comprehensive online programme is exclusively designed for the mineral resources sector, and covers critical issues related to safety, health and the environment. By improving their knowledge

→ *The Mining Resilience Research Institute will examine some of the underlying causes of the underperformance of mining.*

and application ability, the programme enables mine managers to move from being reactive and compliant, to becoming resilient in issues regarding safety, health, the environment and community management.

The establishment of this chair has created new research opportunities, including a noise-induced hearing loss research project. This project is aimed at reducing the noise exposure associated with a scrubber, which is mounted onto a continuous miner. Further research needs in the industry will be identified, and the research focus will be directed as required.

Mining Resilience Research Institute

It is widely acknowledged that mining in South Africa should be a source of economic growth and social transformation. During informal discussions held with a large number of heads of department at the University of Pretoria in 2013, the general perception was that, for a number of complex reasons, mining in South Africa was not meeting the full expectations of investors, government, employees, organised labour, communities and other stakeholders.

The view was expressed that the University could be instrumental in improving the resilience of the mining industry in South Africa by researching some of the underlying causes of the underperformance of mining, and to do so in collaboration with other organisations working on related topics.
This led to a decision to establish the Mining Resilience Research Institute (MRRI), which was officially launched in August 2015.

The MRRI is a multidisciplinary research initiative that will, through rigorous integrated scientific research, contribute practical, implementable solutions, which will, in turn, lead to the increased resilience of the mining industry, and establish the University as a leading international contributor to solutions for complex mining industry problems.

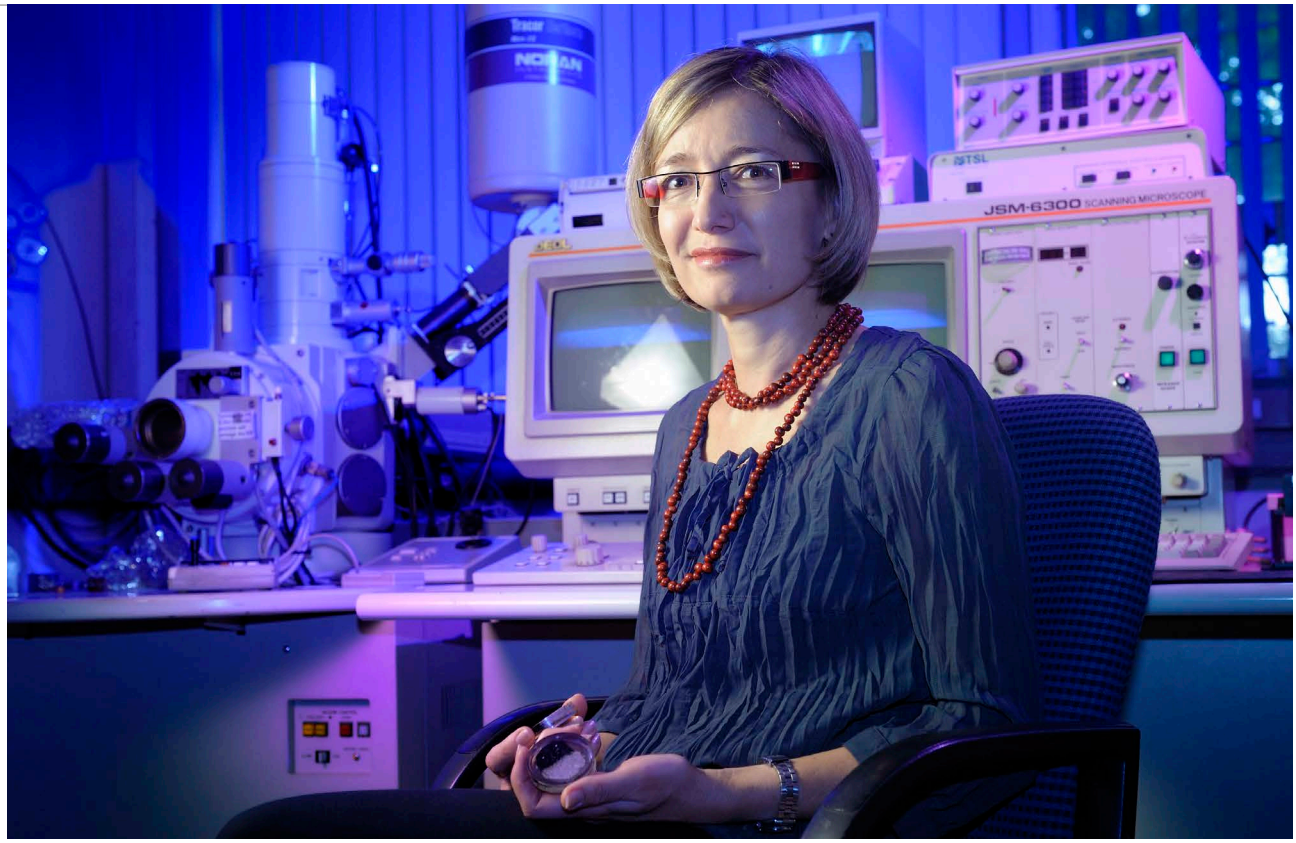
The MRRI forms part of the Sasol Chair in Safety, Health and Environment, and collaboration with the Department of Materials Science and Metallurgical Engineering is envisaged to ensure improved safety, not just during the mining of mineral resources, but also during the subsequent processing of the mined material.

Materials Science and Metallurgical Engineering

The Department of Materials Science and Metallurgical Engineering focuses on research in six key areas in fields related to the processing, refinement and application of mineral resources and the metals extracted from them: pyrometallurgy, welding engineering, minerals processing, hydro-metallurgy, corrosion engineering and physical metallurgy. Four industry-sponsored chairs and an established research institute that conducts contract research for industry enable globally relevant research.

Anglo American Research Chair in Pyrometallurgy

With the establishment of the Anglo American Chair in Pyrometallurgy



Prof Andrie Garbers-Craig, incumbent of the Anglo American Chair in Pyrometallurgy.

in 2009, the concept of a Centre of Excellence in Pyrometallurgy was born. This centre was officially launched on 30 May 2011. The key aim of this Centre is to perform internationally competitive research that is relevant to the local pyrometallurgical industry, thereby bringing the Pyrometallurgy research group at the University of Pretoria and the South African pyrometallurgical industry closer together. Communication, cooperation and support between academia and industry can be strengthened through this collaboration, and expertise in pyrometallurgy can be further developed.

The Centre for Pyrometallurgy is now well established, with ongoing research being conducted in aspects of pyrometallurgy such as ore, sinter and pellets, reductant and flux characterisation, process thermodynamics and mechanisms, process optimisation and development, refractory materials performance characterisation and by-products valorisation.

The group is closely linked to industry with a focus on industry-driven projects. There is a strong focus on experimental studies. It also collaborates with the Glencore Chair in Pyrometallurgical Modelling to address the direct needs of the South African pyrometallurgical industry. These research groups boast well-equipped, high-temperature laboratory facilities and software tools.

Glencore Chair in Pyrometallurgical Modelling

The Glencore Chair in Pyrometallurgical Modelling aims to support local industry with basic and applied research to promote knowledge transfer in the field of pyrometallurgical processes and related materials with a specific focus on the measurement and modelling of material physiochemical properties, computational thermochemical analysis, process modelling, multiphysics modelling and techno-economic modelling.

The research programme is closely linked to industry needs and boasts excellent equipment, hardware and software.

Multiphysics models of high-temperature smelting and sintering furnaces are being developed to improve process understanding and ultimately enhance performance in the ferrochrome and platinum industries. Multiphysics models require high-quality material property data at high temperatures to provide accurate modelling results. Such data is often not available. For this reason, an electromagnetic levitation cell is being developed to determine the physiochemical properties of various materials at high temperatures in a non-contact environment. The thermochemical properties of vanadium-containing oxide solutions are also measured and modelled to make it possible to study South Africa's vanadium extraction processes using thermochemical modelling techniques.

The Pyrometallurgy Modelling research group aims to provide highly skilled engineers and develop world-class computational facilities to support the South African pyrometallurgical industry so that it can maintain and enhance its international competitiveness.

→ *Materials science research examines the processing and refining of mineral resources into viable materials.*

South African Institute of Welding Chair in Welding Engineering

This chair focuses on postgraduate research in welding engineering and the postgraduate training of welding engineers and technologists according to fully accredited international programmes. Welding engineering is a scarce skill, and the industry relies on the delivery of graduates who are qualified according to the requirements of the International Institute of Welding (IIW) and are accredited as international welding engineers and technologists.

The training programme of the IIW is the only system recognised by training and accreditation entities worldwide such as the International Systems Organisation (ISO) and the European Committee for Standardisation (CEN). Locally developed course material is supplemented by internationally approved web-based multimedia distance learning material developed in Germany.

About 15 full-time and part-time postgraduate students conduct research in the on-campus welding laboratory and at the facilities of various industrial partners. This includes research on the welding of industrially important base metals, mainly carbon steels and stainless steels, and the characterisation of the welded joint. Some undergraduate students also conduct welding research.

Tenova-Bateman Chair in Minerals Processing

The Tenova-Bateman Chair in Minerals Processing was established in 2012. Its key aim is to perform internationally competitive research that is relevant to the local minerals processing industry, thereby bringing the Minerals Processing research group closer to the minerals processing industry in South Africa.

Industrial Minerals and Metals Research Institute

The Industrial Minerals and Metals Research Institute (IMMRI) was founded as a partnership between the University of Pretoria and the then Iscor to provide high-level support to the steel industry and to support research and education by making sophisticated equipment and expertise readily available to researchers and students in the Department of Materials Science and Metallurgical Engineering. The successful partnership with industry has been maintained and built over the years and today IMMRI serves as one of the specialised service providers for Arcelor Mittal with a focus on supporting production at Arcelor Mittal South Africa.

The focus of the service and research activities of IMMRI is on physical metallurgy, fabrication processes and protective coatings. IMMRI has established itself as a service provider of choice in these fields for the local industry. It also contributes to the development and application of microalloyed steels through participation in international development programmes and local skills development through research, publications and seminars. Funding from industry partners is leveraged to support and align university research at both undergraduate and postgraduate levels.

Collaboration and innovation create interesting undergraduate studies

Rachel Fischer and Erin Klazar

In the past three years, the Department of Information Science has put a great deal of effort into integrating innovation into its research and teaching activities. The popular academic slogan, "publish or perish", has contributed to this impetus. Demanding circumstances have led to creative solutions.

One of these was the reinvention of the course curricula to contribute to research in undergraduate modules. There is a broad scope of opportunity for research and publications on teaching methods at university level, as well as possibilities to present workshops on these methods.

The African Centre of Excellence for Information Ethics (ACEIE), hosted in the Department of Information Science and funded by the national Department of Telecommunication and Postal Services (DTPS) and the United Nations Educational, Scientific and Cultural Organisation (UNESCO), played a pivotal role in adapting these curricula.

The ACEIE's focal points are as follows:

- Research on information ethics-related issues
- Creating an Information Ethics curriculum to be rolled out at universities across Africa
- Presenting work-shops dealing with information ethics-related issues at university and government level across South Africa and Africa

Faced with issues raised across all levels of interaction, from government officials to university lecturers, the Centre could do research on critical questions related to information ethics and apply it in class. Similarly, the lessons learned in the classroom could be applied to the ACEIE's interaction with government and the private sector. The results of workshop presentations and classroom lecturing activities have truly synthesised the two separate spheres.

Furthermore, what initially started off as a solution to new research demands on personnel, has resulted in published articles and numerous conference and workshop presentations.

An Information Ethics curriculum is being developed that will be rolled out at universities across Africa.

Classroom activities

New content and research opportunities have been inspired by the modules offered by the Department of Information Science, the lecturers presenting them and interaction with government and industry.

INL 140 – Information Science: Introduction to Information and Communication Technology

Intel and Intel Security collaborated with the Department on a concept for a volunteer project between Intel and universities in South Africa. The University of Pretoria was selected to host the pilot project. Students were instructed to create videos in which they had to address set topics, targeted at the level of their younger sisters, brothers or cousins who were still in school (between the ages of 11 and 14). Together with these videos – on whichever devices were available – the students had to develop a five-step slogan that would be striking enough to remember when confronted with a cyber-related issue. The five best videos were selected and presented during the Intel Security Cyber Safety Day on 21 October 2014.
The best group received prizes from Intel, and since then, Intel has become interested in using the videos to raise awareness in other regions where they plan to roll out similar projects.

INL140 Cyber Safety Day on 21 October 2014. Front (from left): Andre Christian (Intel), Erin Klazar (Information Science), Videsha Proothveerajh (Country Manager: Intel), four of the INL 140 student winners, Michael Ingoldby (Intel Security) and Susanna Ackermann (Intel). Back (from left): Coetzee Bester (Director: ACEIE) and Prof Theo Bothma (Head of the Department of Information Science).

INL 240 – Information Science: Social and ethical impact

Students of INL 240 were each required to do research on one of five set themes related to information ethics. They also had to write academic articles on these issues and present them during a student conference. The experience gained and the research conducted resulted in an article, as well as numerous conference and workshop presentations. An article on this specific experience, "Teaching Information Ethics at second-year level at the University of Pretoria: a case-study of integrating theoretical information ethics with practical application", by Erin Hommes (Klazar) and Rachel Bothma (Fischer), was published in the *Innovation Journal*.

This year, the third Undergraduate Information Ethics Conference was held on the Hatfield Campus. It has so far produced a multitude of student articles and presentations, but its greatest contribution is that it annually gave the best group the opportunity to present at the student leg of the Annual Department of Information Studies International Conference, held at the University of Zululand.

JCP 202 – Community-based project

The success of the INL 140 pilot project led to the realisation that the five-minute videos and awareness-raising campaigns should not be limited to university students. They could be repackaged and presented to communities who might be experiencing similar cyber-related issues.

Since all second-year students in engineering, built environment and information technology must enrol for the Community-based Project (JCP 202) module, the coordinator, Dr Martina Jordaan, was consulted to gauge the probability of integrating aspects of the lessons learnt in INL 140 and the content developed in INL 240 in a repackaged form. This would be presented to targeted communities as part of community-based projects.

Since the initial Cyber Safety Day, Intel, the ACEIE and the Department of Information Science has renamed this cluster of projects the Digital Wellness Project. This allowed the realignment of content and module objectives to ensure that a golden thread runs throughout these three undergraduate modules.

The way forward

Following the World Summit on the Information Society (WSIS), the ACEIE and the Department of Information Science sought to address Action Line C10, contained in the WSIS+10 Action Lines, in the above modules in particular. This action line refers to the ethical dimension of the information society, and states that this society "should be subject to universally held values and promote common good, and … prevent abusive uses of ICTs".

The interdependency of food, energy and water in the quest for a sustainable future

Food, energy and water security forms the basis of a resilient economy, but as a water-scarce country with little arable land and a dependence on coal-fired power and oil imports, South Africa's economy is testing the limits of its resource constraints. The World Wide Fund for Nature (WWF) believes that a possible crisis in any of the three systems that make up the food-energy-water nexus will directly affect the other two and that such a crisis may be imminent as the era of inexpensive food draws to a close (Von Bormann and Gulati, 2014).

According to research commissioned by the WWF (Von Bormann and Gulati, 2014), what is known as the food-energy-water nexus revolves around the complex relationship between food, water and energy systems from the perspective of a sustainable and secure future for South Africa.

Water is a prerequisite for food production. It is also a prerequisite for energy production and an important input in producing fertilizers and agricultural chemicals, growing crops, raising livestock and accessing marine food resources. Both water and energy are required throughout the food value chain to process, package, transport, store and dispose of food. Furthermore, water supply systems consume energy at every stage of the water production and supply chain: water abstraction, treatment, distribution to end-users, waste-water reticulation and treatment. Finally, both energy and food production can significantly affect the quality of water bodies.

The food-energy-water nexus is central to the sustainability of South Africa's future. Unless all three elements of the system are in balance, communities cannot flourish. However, we are now faced with a system that is alarmingly out of balance, and a sustainable supply of water, food and energy is becoming increasingly less certain. Effectively averting a crisis requires enhanced information, coordinated planning and adaptation to a resource-scarce future. A flourishing economy underpinned by resilient ecosystems that can produce sufficient water, energy and food security for all into the future depends on it (WWF, 2014).

The uneven distribution of South Africa's natural resources and the location of economic development nodes in the country amplify the management constraints and inequality of access to these resources. A clear example is the fact that South Africa's coal deposits coincide with the country's best agricultural land and sources of some of the major inland rivers. This spatial complexity impacts on the effective management of food, energy and water resources, making it the foremost challenge for sustainable development in South Africa (Von Bormann and Gulati, 2014).
Until now, there has been limited recognition of the interdependence of food, energy and water from a policy and sectoral perspective. Failure to accurately understand the synergies and trade-offs between these three resources will result in millions of South Africans being at risk of hunger, waterborne diseases, energy shortages and increasing poverty (Von Bormann and Gulati, 2014). Ultimately the challenges posed by resource constraints point to a looming crisis in the provision of clean water, electricity and nutritious food, which are at the heart of national security and welfare.

According to the WWF's research, this response must focus on the effective management of resources, enabled by wider technology use and greater governance. This should be underpinned by an integrated approach to policy, planning, development and appropriate institutional capacity.

Implications for food security

The links between energy and food systems mean that energy supply and prices exert pressure on the ability of the agricultural sector to supply affordable food. The availability and cost of energy is also critical for the country's water security. According to Von Bormann and Gulati (2014), the often unconsidered cost of the economy's dependence on interbasin transfers, which require substantial amounts of energy, means that the country is already consuming large energy volumes to overcome the challenges related to its water scarcity.

South Africa's energy requirements are growing,

The reliance of water supply systems on energy means that an energy shortage and rising energy prices pose challenges to water security.

and could have serious potential impacts on water requirements in future. It is projected that 65% of the country's electricity needs will still be met by coal-fired power stations in 2030 (Von Bormann and Gulati, 2014), which will continue to place high demands on the country's limited water resources. Ironically, the country's coal deposits coincide with the best agricultural land and important water catchment areas. The continued dependence on coal for meeting electricity requirements will therefore directly conflict with food production and impact on the quality of water resources.

New energy sources, such as non-conventional oil and gas production through hydraulic fracturing, and technologies such as carbon capture and storage, may be able to lower the carbon emissions of coal-fired power plants by 80 to 85%. However, these methods of fuel production are water intensive, and will only add to the pressure on water resources.

Implications for water security

The reliance of water supply systems on energy means that an energy shortage and rising energy prices pose challenges to water security. Energy shortages, specifically electricity shortages, can affect the reliability of water systems and water supply services. The rising cost of energy could also have a substantial effect on the actual cost of water supply services, necessitating tariff hikes for these services (Von Bormann and Gulati, 2014).

In South Africa, fresh water is predicted to become the determining constraint on development. However, the challenge is not only an issue of water availability; it is predominantly an issue of declining water quality. According to the WWF report, inadequate investment in water-related infrastructure that could maintain water quality at sufficient levels has added to the poor water quality.

Energy shortages can affect the reliability of water supply services, which in turn affect food security.

South Africa's commercial agriculture production is heavily dependent on irrigation, with only 12% of the total land surface area considered suitable for growing rain-fed crops, and less than 3% considered truly fertile (Von Bormann and Gulati, 2014). Irrigation accounts for 90% of vegetable, fruit and wine production, and 12% of the total area under wheat is irrigated. Therefore, although 1.5% of the land is under irrigation, this currently accounts for 30% of the country's crops (Von Bormann and Gulati, 2014). As there is limited arable land, the only feasible way to grow the agricultural sector is through irrigation.

In the food value chain, the largest proportion of water is embedded at the agricultural product stage, as opposed to the processing stage. Every product has virtual water (Von Bormann and Gulati, 2014), which represents the water embodied in the inputs required to produce the final product. The largest proportion of crop water and animal products is green water (rainfall), which is a full order of magnitude larger than blue water (irrigation) use. However, abstracted or blue water is associated with higher environmental and financial costs, such as water depletion, salinisation and soil degradation (Von Bormann and Gulati, 2014).

Implications for energy security

The country's impending water scarcity also poses a challenge for future power generation plans and electricity supply. The supply of electricity depends on water-intensive coal-fired power stations, which account for 86% of generation capacity (Von Bormann and Gulati, 2014). Efforts are being made to transition to dry-cooled coal-fired power stations, which need 5 to 10% of the water required by wet-cooled stations. Nevertheless, these power stations are still entirely dependent on water, and there is a high co-dependency between water and electricity production.

The food-energy-water nexus is not so much about the resources themselves, as it is about the relationship between them. Addressing the nexus therefore requires a quantum shift in thinking. If we are to avert a crisis in natural resource management, and ensure the national security of South Africa through the provision of clean water, electricity and nutritious food, we urgently need to identify the trade-offs and synergies at a local, national and regional scale, and recast the governance approach.

According to Von Bormann and Gulati (2014), if the necessary transformation is to occur, it must be based on sound science, accurate data and integrated, effective national policies and regulations that are consistently enforced.

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Harnessing new technologies to manage climate change

John Ouma-Mugabe

Nowhere in the world is the interaction between climate change and agriculture as vivid as it is in Africa. Africa's agriculture and other economic activities depend heavily on water, a climate-sensitive, non-renewable resource, which affects the biodiversity and natural resources on which all living beings depend for their survival. Agriculture, which employs at least 30% of the continent's population, is a rain-fed industry. Other economic activities, such as tourism and fisheries, are also affected by weather conditions. This makes the continent's economies particularly vulnerable to climate change.

Socio-economic context

Africa is perhaps the region in the world that is most vulnerable to the impacts of climate change and environmental degradation. Extreme weather conditions are causing arid regions to become even more arid, leading to a decline in agricultural production. According to a recent article by Temesgen Deressa (2014), a guest scholar at the Brookings Africa Growth Initiative, climate change-related phenomena – particularly droughts and floods – have caused a significant economic slowdown in Africa.

Floods and sporadic rainfall, for example, have reduced the growth in Mozambique's gross domestic product (GDP) by more than 1% per year, and have cost Zambia US$4.3 billion in GDP over ten years (Deressa, 2014). There has also been an increase in the number of undernourished people by approximately 20% in Eastern Africa and 2% in Southern Africa according to the Food and Agriculture Organisation (FAO) of the United Nations (FAO, 2015). In addition to malnutrition, the people of Africa are becoming more exposed to diseases such as malaria, which kills millions of inhabitants every year.

Food insecurity increases vulnerability to HIV and Aids. In a paper presented at the FAO's International Workshop in Tivoli, Italy, in September 2003, Loevinsohn and Gillespie (2003) list factors that affect susceptibility to HIV. This includes malnutrition, which increases the likelihood of infection, lack of food or access to food, which increases the probability of women being forced to engage in commercial sex to feed their families, and the search for food, which leads to migration to urban areas, increasing exposure to HIV.

Climate change will also have an irreversible impact on Africa's natural assets and infrastructure. A rise in the sea level will erode mangrove forests and destroy infrastructure in coastal cities such as Cape Town, Dakar, Dar es Salaam, Maputo and Mombasa. The economic and social costs of such impacts are likely to be huge.

Most countries in Africa tend to rely on external sources of financing or development assistance to address climate change and challenges related to food security.

Conventional approaches

Governments in most African countries have adopted strategies for climate change adaptation and food security. In South Africa, the National Development Plan 2030 (NDP) (National Planning Commission, 2013) outlines a number of actions to address climate change and improve food security, including the expanded use of irrigation. The NDP recognises the roles that science, technology and innovation can play in climate change mitigation and adaptation, as well as in increasing agricultural productivity for food security. It emphasises the need to increase the investment of government and the private sector in low-carbon energy technologies and irrigation.

Most African countries have tended to rely on external financing or development assistance to address climate change and challenges related to food insecurity. Countries' climate change adaptation and mitigation plans have been designed in

→ *Governments in most African countries have adopted strategies for climate change mitigation and food security.*

anticipation of foreign funding. The emphasis on external financing is often based on the premise that industrialised countries contribute more to the emission of greenhouse gases and climate change in general, and thus have an obligation to provide resources to African countries. African countries are thus becoming more dependent on external sources of funding, foreign technology transfer and food aid to address the challenges of climate change and food insecurity. Most countries have relatively weak endogenous scientific and technological capabilities to effectively engage in climate change mitigation and adaptation. Dealing with climate change and building food security will require policy measures to enable countries to grow appropriate and capable research and innovation systems.

Taking technology policy considerations

African countries will be participating in the 21st Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) in Paris, France, in December 2015. They have a rare opportunity to shift their emphasis from seeking external funding and technology transfer to building international partnerships that will enable them to grow their national systems of research and innovation in climate change.

There are three technological policy issues on which African countries should focus and possibly negotiate at the COP. The first is international support for national innovation and technology policy design and implementation. Most countries on the continent have limited capacity for technology policy analysis and development. In order to address this challenge, it is crucial that the UNFCCC's technology mechanism supports training in innovation and technology policy at the request of African governments. The COP will need to allocate resources to the technology mechanism for it to address the African demand for building policy analysis capacity.

In order to effectively address challenges related to climate change and food security, African countries need well-configured institutional arrangements that harness technical skills at universities and in industry.

The second issue pertains to strengthening national capacity for technology needs assessment and technology road-mapping. Conducting a technology needs assessment and developing related technology roadmaps are vital for appropriate national research and development, and innovation policy. Countries that are unable to undertake technology needs assessments and to develop roadmaps will experience difficulties in developing and/or procuring climate change, agriculture-friendly technologies in cost-effective ways.

By 2013, 36 African countries had technology needs assessment reports. Most of these countries' reports are outdated and tend to have a narrow focus on energy technologies. They are also not backed by appropriate technology roadmaps that are essential for technology prospecting.

Technology prospecting is the process of searching for, identifying, choosing and acquiring specific technologies. It is usually based on a technology needs assessment and technology roadmaps.

In order to effectively engage in climate change mitigation and adaptation, and to address challenges related to food insecurity, African countries need well-configured institutional arrangements that harness and use technical skills at universities and in industry. The links in most countries between universities and industry are weak. Without university-industry collaboration, innovation chasms will persist and countries will be denied the opportunity of generating knowledge and using skills to develop climate change technologies that have greater agricultural applicability.

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Architecture regenerates and transforms societies and their habitats

One day a fire broke out in the bush. Once they were a safe distance away, all the animals watched with devastation as their homes were consumed by flames. Except for the hummingbird. The little bird picked up drops of water in its beak and tried to put out the flames. It kept going to and fro. The other animals were perplexed, and ridiculed the bird. Obviously, these small drops of water would never put out the fire. The hummingbird replied: "Yes, but I'm doing the best I can."

This is a story about never giving up, but it is also a story of the mindshift that is vital if humans want to leave behind a better world for future generations. It is the responsibility of each and every person on this planet to do what they can. For Prof Chrisna du Plessis, newly appointed Head of the Department of Architecture in the School for the Built Environment, this goes beyond putting out the fires created by our current lifestyles and socio-technological pathways, as sustainability aims to do.

She explains: "The underlying premise of my current work is that, in order to ensure a future within which coming generations of all species can thrive, we need more than sustainability – we need to adapt to the changes already in place and create an environment that allows us to be resilient; and we need to regenerate and transform our societies and their habitats, bringing new life and creating new ways of being in the world."

These are the challenges explored by TRUST (Think Tank on Resilient Urban Systems in Transition), an informal research group headed by Prof Du Plessis and Prof Karina Landman of the Department of Town and Regional Planning. They form part of an international network of architects, planners, designers and academics who are developing an understanding of the built environment that sees our towns and cities as socio-ecological systems in which humans and their technological and social artefacts are part of the community of life we call nature.

They share a commitment to healing the broken relationship between humans and the living systems of which they are part, and to participating in creating a "state of evolutionary health". This needs a number of shifts in how we think about the form and processes of the built environment and how these align with the lessons we can learn from nature on how resilient and thriving living systems function.

The first major shift in thinking is a transition from focusing on the building or infrastructure as a technological object towards seeing it as part of a larger system.

The second is that the things we do in the built environment should contribute to the functioning of this larger system in a way that keeps it healthy and grows its potential to adapt to change and regenerate itself.

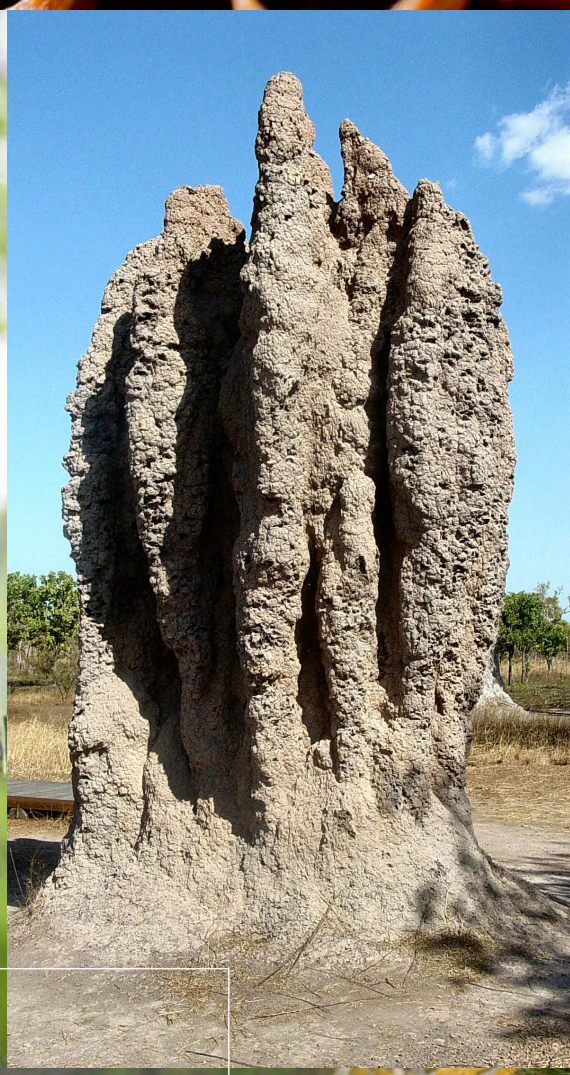
The third shift is to understand that the development of such regenerative urban systems is based on collaboration, not only between professional and scientific disciplines, but also with the communities who are part of the living systems with which we work.

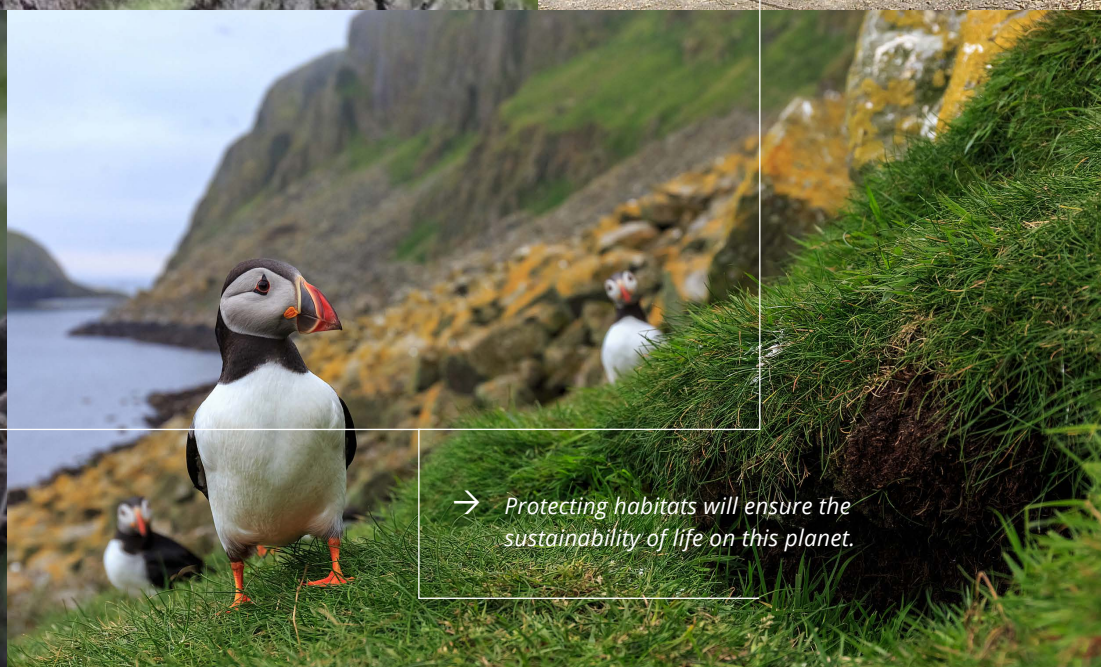
The question is: How does this work in practice? What is the contribution of Prof Du Plessis and, ultimately, the University of Pretoria?

Philosophy turned into practice

Prof Du Plessis works to accomplish this in three ways. The first is by exploring the translation of resilience theory into the urban system and the practical implications this has for urban form and function. She has been working on this with Prof Landman, Prof Serge Salat of the Urban Morphology and Complexity Institute in Paris, and a number of postgraduate students. The first results from this work clearly show that it is possible to translate concepts taken from ecological resilience theory, such as functional response diversity and connectivity, to the urban context, and furthermore, that these characteristics influence social resilience. They plan to take this further by exploring the relationship between social and spatial resilience; in other words, how our urban form and the spatial distribution of functions such as shelter, retail and transport help or hinder social resilience.

The second branch of her work is to develop and define the theory of regenerative design and





→ *Protecting habitats will ensure the sustainability of life on this planet.*

development. The book *Designing for hope* (co-authored with Dr Dominique Hes of the University of Melbourne) and the documentary *The regenerates* (also produced in collaboration with Dr Hes) present the first formal exposition of this emerging field internationally. This work illustrates and refines these theoretical constructs by exploring case studies of regenerative practices in planning, design (of buildings, landscapes or urban contexts) and professional practice. One of the main findings of the research for *Designing for hope* was the importance that the various practitioners interviewed placed on deep personal transformation as a condition for the behaviour change that will result in meaningful planetary transformation.

Exploring the ways in which such transformation can be encouraged forms the third aspect of her work. This is where her research links most closely to her teaching practice.

Teaching

Through the third-year module Prof Du Plessis teaches in Sustainable Construction, she endeavours to stimulate this personal development in her students. Apart from teaching basic sustainability literacy and practices aimed at developing practical, creative and reflective problem-solving and evaluation skills, students in the Sustainable Construction module are taken on a journey of self-discovery, as the self is the place where any change starts. Students are guided through a set of experiential exercises to help them understand their own contribution to the problem, and develop scenarios for alternate futures, experiencing the interrelatedness of the world, and exploring ways in which they can bring about change within their own sphere of influence.

This is exactly where the story of the hummingbird becomes so relevant. When confronted with the problems of environmental degradation, climate change and social inequality, students express sentiments of discouragement: "The problems we face are so big. How can I possibly make any difference?"

The hummingbird's message is that everyone's contribution is significant. The course makes students aware of three independent principles: working with what is in one's sphere of influence, that small changes can have big results (the butterfly effect), and the fact that the world in which we live is created by the actions of people.

Working with what is in one's sphere of influence means trying to change things over which one has a direct influence. The premise of this is that the ripples of one's actions will inspire others to follow suit. The butterfly effect proposes that one small action has the potential to create the momentum necessary to affect the behaviour of the larger system. The third principle, which is also the foundational principle of the ecological world view, states that "the world in which we live is constantly being created not by governments or large organisations, but by the individual actions of people and other organisms (agents) and their responses to the actions of other agents and changes in their environment".

It is important to send future architects, construction managers, quantity surveyors and property developers into the world with not only the right skills, but also a positive frame of mind, as well as a holistic perspective on how they can contribute to creating a better world. That is the ripple effect Prof Du Plessis wants to put in motion through her teaching and research.

The ripple effect

As Tshwane is the capital city of South Africa (and the city in which the University is located), it presents an ideal research opportunity for finding solutions to challenges that face the city, society and our world.

Prof Du Plessis, together with Prof Landman and other members of TRUST, collaborates with academics from various faculties on the Capital Cities (Space, Justice and Belonging) institutional research theme to introduce some of this thinking to the city.

This research field reaches into aspects of every discipline on the planet, as man and man-made objects are part of living systems. This is a complex and comprehensive concept to get one's head around, but once one does, one realises the immense potential it has for actually changing the world. Perhaps this is ***the*** answer.

But what happened to the hummingbird? The Great Being took pity on it and sent a rainstorm to put out the fire.

Who knows what cities can look like if everyone does what he or she can?

TRUST has been established through a National Research Foundation (NRF) grant under the Global Change Society and Sustainability Programme. Its inter- and transdisciplinary research has a particular focus on Tshwane and uses the combined skills of planning, evaluation, design thinking and ecological engineering in an iterative systems approach to accomplish the following:

- Develop an understanding of the social, technical, spatial and biophysical factors that would determine resilience in the various levels of the city.
- Develop appropriate solutions (processes and methodologies) for the planning, design, construction and management of a resilient and regenerative built environment.
- Build national capacity in generating knowledge on, and applying it to the new research area of resilience and the regeneration of human settlements through increased postgraduate research outputs, and continued professional education.

An excellent take on this concept is the documentary *The regenerates*, which synthesises the views of major influencers. It is available at https://vimeo.com/120837455. It will give you a whole new perspective on life.

A fresh perspective on rural development in Gauteng

Prof Mark Oranje

Social deprivation and underdevelopment continues to haunt many rural areas in South Africa. In an attempt to mitigate this, the Department of Rural Development and Land Reform (DRDLR) commissioned Business Enterprises at University of Pretoria (BE at UP) to produce the Gauteng Rural Development Plan (GRDP) at the end of 2014. The Department of Town and Regional Planning, a number of external contractors in civil engineering, geomatics, urban design and agricultural economics, and senior officials in the DRDLR participated in this project.

The GRDP is not only the first integrated, strategic plan prepared for the rural areas of the province, it also represents an attempt to avoid regarding rural areas as only places of farming, isolation, marginalisation, poverty and/or despair. According to the GRDP, rural areas have many opportunities for economic activity, job creation and a better quality of life. In support of this decidedly opportunity-centred approach, the project team introduced a number of novel rural development concepts. These include functional regional rural zones, rural design, and transit-oriented rural development.

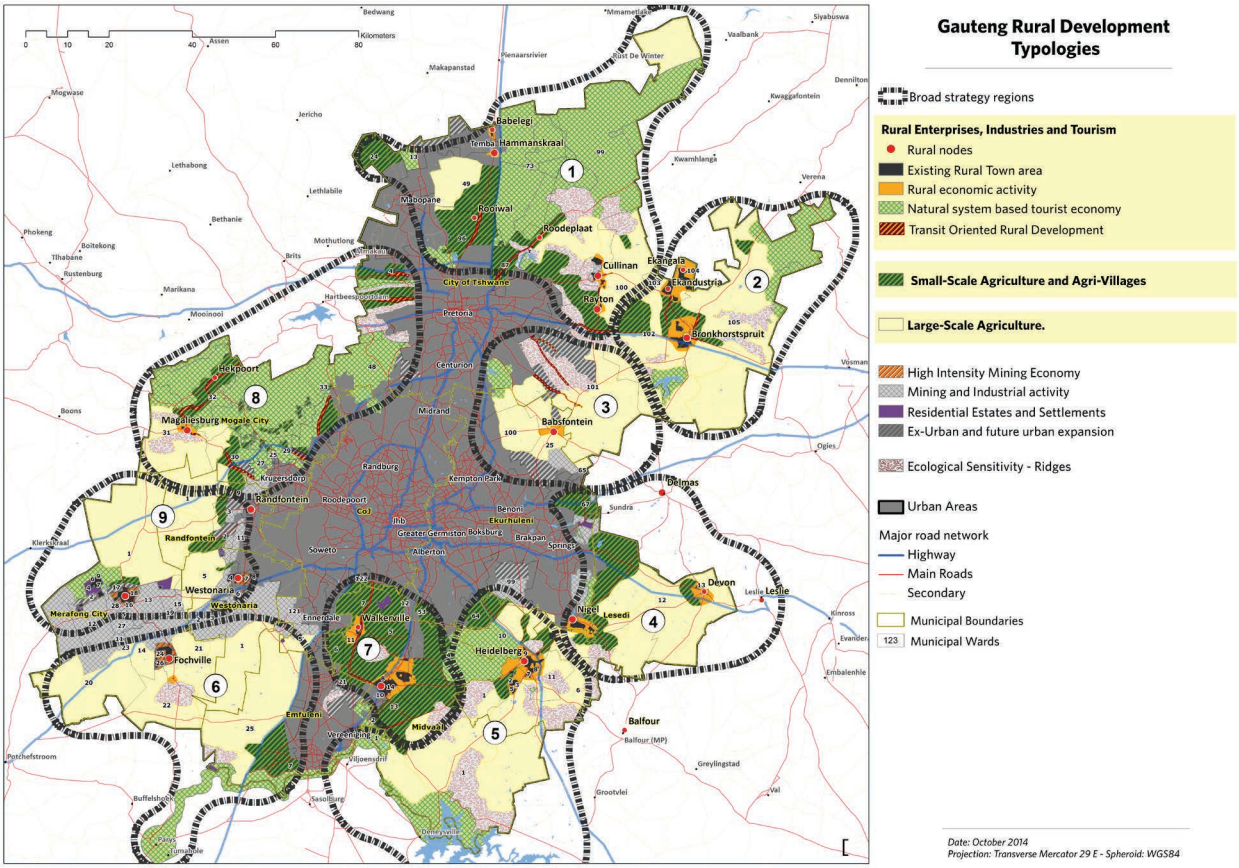
While it was commissioned by the DRDLR, this plan is not a blueprint for any one entity in government. Instead, national and provincial departments and the municipalities in the province, communities and private-sector stakeholders can address common challenges within this development framework. They can also discuss the prospects the province offers and collectively map ways forward in which all those living in the rural parts of the province can lead a dignified and meaningful life.

The plan was conceived, prepared and refined over two years. This was achieved through a number of processes. The first stage included intensive data gathering, site visits, the analysis of data and integration with the legislation, policies, strategies, plans, frameworks, programmes and projects of national and provincial government departments and municipalities. The second stage consisted of geographical information system (GIS) analyses using purpose-made land needs and suitability criteria, and rural development typologies. The third stage included work sessions with DRDLR officials, officials from national and provincial government departments, as well as municipalities and experts in the areas of rural development, engineering services, agricultural economics, and environmental management. During the last stage, distillation of all the data, ideas, inputs, proposals and concerns into the key GRDP outcomes were carried out.

A number of key GRDP outcomes and components were identified. Nine functional rural regions spanning rural Gauteng and – in many cases – "functionally tied" parts of neighbouring provinces were identified. The outcomes and components include nine templates – one per functional rural region – for intergovernmental planning, budgeting and implementation scheduling sessions, as well as a three-phase approach to developing each of the nine functional rural regions. A set of significant "quick gain actions" can be undertaken in Gauteng to meet government's overarching objective of addressing the country's inequality, poverty and unemployment. These actions also contribute to the realisation of government's Outcome 7: "Vibrant, equitable and sustainable rural communities with food security". It does this by means of the following:

- Transforming rural nodes into high-potency, catalytic regional rural development anchors and rural service centres
- Expanding small-scale farming and supporting small-scale farmers and associated agro-processing
- Enabling and supporting transit-oriented rural development (TORD) along suitable provincial routes
- Strengthening and deepening natural system-based tourism in the province

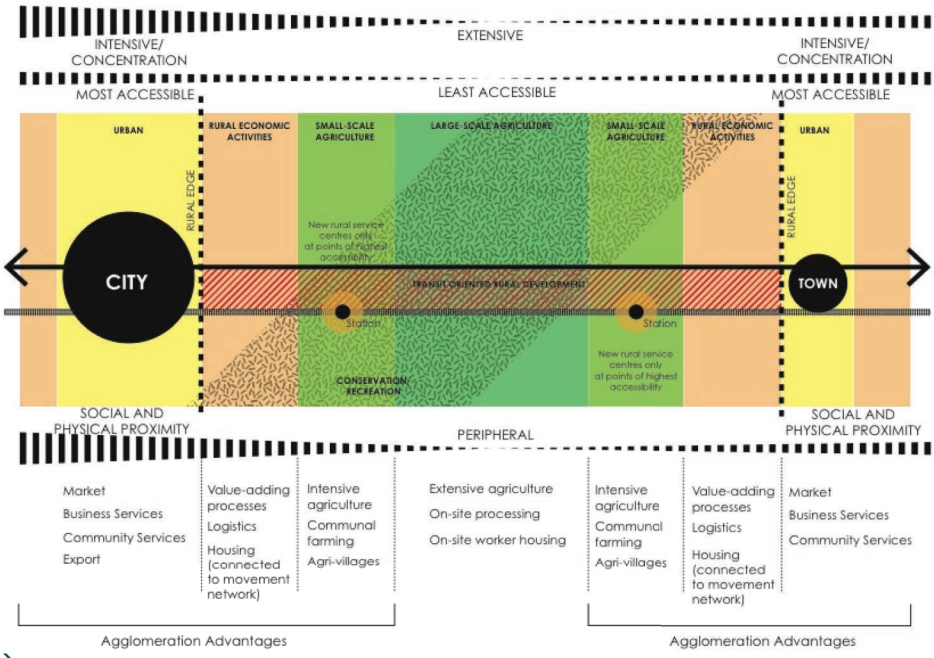
While the implementation of the plan rests on the enthusiastic, sustained and collaborative efforts of a wide range of stakeholders and role-players, the project team proposed that an internal, coordinating DRDLR Advisory Committee be established. It was also proposed that the DRDLR's Spatial Planning and Land Use Management Unit assume the lead role with regard to rural development in the province, as set out



→ *The nine functional rural regions and the three rural development typologies proposed for Gauteng.*

in the plan, and undertake the following tasks on a sustained basis:

- Regular engagement with all relevant stakeholders in and outside the state
- Lobbying and influencing other stakeholders and role-players for the inclusion of the GRDP's objectives, concepts and ideas in plans, frameworks, policies and strategies that have an impact on rural development in the province
- Aligning proposed plans, policies and strategies in the DRDLR with those of other spheres and sectors of government
- Populating and regularly updating the geographical information database with all relevant information about rural development projects and programmes
- Keeping an eye open for new national, provincial and municipal legislation, policies, plans, frameworks, strategies and programmes that may have an impact on rural development in the province, and informing – as and where necessary – the other units in the DRDLR who can contribute to such documents



→ *A conceptual design of the Gauteng urban-rural continuum.*

The project team is of the opinion that, should all stakeholders and role-players play their unique roles, the plan could make a real, positive difference in rural Gauteng and the lives of everyone who lives in this space.

Exploring solutions to South Africa's electricity crisis

As part of its focused research in the field of energy, the University is proud to have a number of acknowledged industry leaders who are engaged in studies across a variety of disciplines to address the energy crisis that is facing South Africa.

One of these specialists who is widely recognised for his expertise in this field is Prof Xiaohua Xia, Director of the Centre of New Energy Systems (CNES) and the National Hub for Postgraduate Programme in Energy Efficiency and Demand-side Management (EEDSM).

A topic of particular relevance, especially within the scenario of load shedding that affects both individuals and businesses, and impacts on the economy, is alleviating the pressure on the national power grid.

As part of the UP Expert Lecture Series, Prof Xia explored the value of EEDSM in addressing this challenge.

EEDSM programmes cover the broad categories of conservation, load management, fuel switching, strategic load growth and self-generation.

So far, EEDSM has saved the country more than 4 000 MW, which is the amount of power Eskom needs to save in its Stage 3 load shedding.

When it comes to power supply, the electricity grid can only be stable if there is a balance between supply and demand. When the grid is unbalanced, there are two options for restoring balance. The first is to increase the supply, such as building new power stations. The second is to decrease demand, such as encouraging consumers to switch off appliances or switching to renewable energy sources. As the construction of new power capacity has been experiencing delays, and is unlikely to contribute to the grid in the short run, it is vitally important to find other short- to medium-term solutions to the energy crisis.

During the Expert Lecture, Prof Xia explored the feasibility of a few of these options. In evaluating energy alternatives, it is important to consider time frames, initial capital investment, maintenance and operation costs, as well as potential energy savings.

Load shedding is probably the least popular option for decreasing energy demand from the consumer's point of view. However, it does not require any capital investment and can be implemented immediately. Although load shedding is able to save between 1 000 and 4 000 MW, it is not a very affordable option, as Eskom and other companies will lose revenue.

Smart meters for pool pumps and geysers function in a similar way to load shedding. The idea is that these meters switch off pool pumps and geysers during the day. In order to save 4 000 MW, these meters would have to be installed in at least 10 million households, which can take years to achieve.

The capital investment is also substantial. The benefit, however, is a very low operational cost.

According to Eskom, 40% of electricity consumed by South Africa's residential sector is used for heating water and 31% for operating kitchenware such as ovens, stoves and hot plates. An Eskom report states that the residential sector used 14 105 MW of Eskom's output in 2013, while other sectors used an aggregated 25 160 MW. Currently, the demand for heat in South Africa is met largely by electricity. However, conversion efficiency from coal to electricity and then to heat is much lower than direct conversion from coal or gas to heat. Coal gasification plants are able to reach conversion efficiencies from coal to heat of around 75%, and from coal to gas and then to electricity of around 40%, which is by far the most efficient technology to generate heat and electricity from coal. The cost of this process is less than half of Eskom's current EEDSM benchmark of R5 million/MW, and the operational cost is about a third that of a conventional power plant. In view of South Africa's large coal reserves, clean coal gasification technology offers a very attractive option.

Self-generation offers another short- to medium-term solution for South Africa's electricity crisis.

Systems such as photovoltaics, wind turbines, co-generation systems and gas-fired turbines to supply part or all of customers' needs (heat/power) will be a convenient way to reduce demand from the grid, and consequently alleviate grid pressure and reduce transmission losses. Co-generation systems installed in industrial plants that produce high temperature waste heat. Captive power plants that utilise biomass or gases are good examples of self-generation.

Solar water heating has a high capital investment of R30 million/MW, which is roughly the same as the Medupi power station. However, the operational costs are considerably lower. The time frame for implementation could be short or long, depending on the efficacy of implementation plans. Once these solar water heaters have been installed, they can be operational for at least 20 years. With solar heating being one of the best sources of renewable energy, a solar water heating programme was started in 2008 to switch fuel usage away from electricity and to promote the uptake of one million units of solar energy by 2015. The targeted saving of the solar water heating programme (miscalculated as equivalent to the generating capacity of an average-sized power plant) was not achieved.

EEDSM remains the best option to alleviate the current crisis. In future, we must focus more on fuel switching to satisfy heat demand, and on self-generation.

Prof Xiaohua Xia is the Director of the Centre of New Energy Systems and the Hub for Postgraduate Programme in Energy Efficiency and Demand-side Management at the University of Pretoria.

He obtained his PhD from the Beijing University of Aeronautics in China in 1989. He was an Alexander von Humboldt fellow of the University of Stuttgart in Germany, and a postdoctoral fellow of the Ecole Centrale de Nantes in France and the National University in Singapore. He joined the University of Pretoria in 1998 and became a professor in 2000.

His research interests include non-linear feedback control, observer design, time-delay systems, hybrid systems, modelling and control of HIV/Aids, the control and handling of heavy-haul trains, and energy modelling and optimisation.

Prof Xia is a professional engineer, registered with the Engineering Council of South Africa, a fellow of the Institute of Electrical and Electronics Engineers (IEEE) and a certified measurement and verification professional registered with the American Association of Energy Engineers.

Earlier in 2015, Prof Xia was appointed to the Ministerial Advisory Council on Energy (MACE), which comprises experts across the energy spectrum. He is serving a two-year term. The Council will be a non-statutory body and will be solely advisory in character. It will primarily focus on the coordination of national dialogue and the provision of cross-sectoral advice to the Minister on Energy on the strategic direction and policy development imperatives of the energy sector in South Africa.

Research team at the helm of new ISO Standard

Any digital investigation requires a high level of expertise. Those involved in the investigation have to be competent, proficient in the processes used and they have to use validated processes that are compatible with the relevant policies and/or laws in applicable jurisdictions.

Prof Hein Venter, an associate professor in the Department of Computer Science, served as the editor of a new International Organization for Standardization (ISO) standard in information technology that relates to incident investigation principles and processes.

ISO is an independent, non-governmental membership organisation and the world's largest developer of voluntary international standards. The organisation consists of 162 member countries.

International standards stipulate world-class specifications for products, services and systems to ensure quality, safety and efficiency. They are instrumental in facilitating international trade, and more than 19 500 international standards covering almost every industry – from technology to food safety and healthcare – have been published.

ISO does not decide when to develop a new standard, but responds to a request from industry or other stakeholders such as consumer groups. Typically, an industry sector or group communicates the need for a standard to its national member, who then contacts ISO. South Africa's member organisation is the South African Bureau of Standards (SABS).

The international community acknowledged the need for such a standard when Prof Venter first proposed it during an ISO meeting in Berlin in 2010. He contacted the SABS with his proposal and ISO granted him permission to initiate the process of developing the standard.

After five years of following the comprehensive ISO process, the research efforts of Prof Venter and students of the Information and Security Architectures (ICSA) Research Group culminated in the publication of the International Standard ISO/IEC 27043 on 9 March 2015.

This standard is an "umbrella" standard that describes the width of the overall process to be followed when conducting a digital forensic investigation. It paves the way for other international standards that will cover the depth of each subprocess within the overall process.

This international standard provides guidelines that encapsulate idealised models for common investigation processes across various investigation scenarios.

This includes processes from pre-incident preparation up to and including returning evidence for storage or dissemination, general advice on processes, as well as the appropriate identification, collection, acquisition, preservation, analysis, interpretation and presentation of evidence.

A basic principle of digital investigations is repeatability, where a suitably skilled investigator working under similar conditions should be able to obtain the same result as another similarly skilled investigator. This principle is exceptionally important to any general investigation.

Guidelines for many investigation processes have been provided to ensure that there is clarity and transparency in obtaining the produced result for each particular process. Established guidelines that cover incident investigation principles and processes would expedite investigations, because they would provide a common order of the events that an investigation entails.

Established guidelines allow smooth transition from one event to another during an investigation, and such guidelines would allow the proper training of inexperienced investigators. The guidelines also aim to assure flexibility within an investigation, due to the fact that many different types of digital investigations are possible. Harmonised incident investigation principles and processes are specified, and indications of how the investigation processes can be customised in different

The research of Prof Hein Venter and his students culminated in the publication of ISO/IEC 27043.

investigation scenarios are provided.

A harmonised investigation process model is necessary in criminal and civil prosecution settings, as well as in other environments, such as corporate breaches of information security and the recovery of digital information from a defective storage device.

The guidelines provide succinct guidance on the exact process to be followed during any kind of digital investigation in such a way that, if challenged, the adequacy of the investigation process that was followed during such an investigation cannot be questioned.

When it is necessary to assign a process to a person, that person will take responsibility for the process. Therefore, a strong correlation between a process responsibility and a person's input will determine the exact investigation process required according to the harmonised investigation processes provided as guidelines in this international standard.

This international standard follows a top-down approach. This means that the investigation principles and processes are first presented on an abstract level before more details are given.

For example, a high-level overview of the investigation principles and processes are provided and presented in figures as "black boxes" at first, whereafter each of the high-level processes are divided into more detailed processes.

Therefore, a more detailed view of all the investigation principles and processes are presented near the end of the international standard process.

This international standard complements other standards and documents that provide guidance on the investigation of security incidents.

It is not an in-depth guide, but a guide that provides a rather wide overview of the entire incident investigation process.

This guide also lays down certain fundamental principles that are intended to ensure that tools, techniques and methods can be selected appropriately. They should also be shown to be fit for purpose should the need arise.

Approved

International standards stipulate world-class specifications for products, services and systems to ensure quality, safety and efficiency.

The SKA is helping to bring Africa into the knowledge economy

Dr Bernie Fanaroff, Project Director of the South African Square Kilometre Array (SKA) Telescope Project, was the speaker at the annual Hendrik van der Bijl Memorial Lecture held at the University of Pretoria on 17 June 2015. This event, presented in collaboration with the South African Academy of Engineering, has been held since 1963 to commemorate the contribution to the industrial and scientific development of South Africa by Hendrik van der Bijl, Chancellor of the University from 1934 to 1948.

Prof Cheryl de la Rey, Vice-Chancellor and Principal of the University of Pretoria, welcomed Dr Fanaroff, and expressed her pleasure at having someone of his calibre address the audience. The University looks forward to increasing its collaboration with the SKA, and is grateful for the many opportunities it presents for leading research initiatives, particularly in the Faculty of Engineering, Built Environment and Information Technology.

The SKA is a global project to build the world's largest radio telescope. It will revolutionise our understanding of the universe. Approximately 100 organisations and companies from 20 countries are participating in the design and development of the first phase of the SKA (SKA1). This includes the construction of two instruments to observe the universe at different radio frequencies. SKA South Africa, together with industry and university partners, is playing a leading role in the design and development of SKA1.

During SKA1, a core array of 199 mid-frequency dish antennae spread over 150 kilometres will be constructed at the Losberg site in the Karoo. This will incorporate the 64-dish MeerKAT radio telescope. The SKA Organisation will also build 125 000 low-frequency antennae in Western Australia.

The SKA is the source of significant innovation.

The project, which will be in operation for at least 50 years after its construction, will result in transformational science that will see thousands of dish antennae and up to a million dipole antennae being designed and constructed in the second phase of the SKA (SKA2). This will enable astronomers to monitor the sky in unprecedented detail.

The MeerKAT antennae will generate huge data sets that must be processed and matched to data from other telescopes. By developing the skills needed to analyse such large data sets through the SKA, the project is contributing to the development of skills and capacity to address the problem of processing what is known as Big Data. These skills can then be leveraged to develop scientific communities and knowledge that can be applied to wider challenges in the fields of science, technology and engineering. SKA South Africa subsequently developed the Big Data Africa Programme.

The SKA is the source of significant innovation, including the development of the "industrial" techniques that are required to build an industrial-scale telescope. According to Dr Fanaroff, the greatest challenge to the project is radio interference. As a result, all digital electronic devices need to be well

Celebrating the 52nd annual Hendrik van der Bijl Memorial Lecture are (from left): Prof Cheryl de la Rey, Vice-Chancellor and Principal, Dr Bernie Fanaroff, Project Director of the SKA, Mr Bob Pullen, Chairperson of the South African Academy of Engineering, and Prof Sunil Maharaj, Dean of the Faculty of Engineering, Built Environment and Information Technology.

sealed, and a project has been launched to provide farming communities in the surrounding rural areas with satellite equipment for their internet and telephony needs to prevent digital signals from interfering with the radio antennae.

Through its very successful human capital project, the SKA is succeeding in building a representative and vibrant astronomy and instrumentation community in South Africa, which is contributing to socio-economic development. It is also changing attitudes towards skills in Africa by raising the profile of science and technology on the continent and developing world-leading capacity in this field.

In preparation for SKA2, skills, regulations and institutional capacity are being developed in partner countries in Africa. A network of very long baseline interferometry (VLBI)-capable radio telescopes is also being developed on the African continent. The development of the African VLBI Network (AVN) is aimed at transferring the skills and knowledge necessary for the SKA to the countries that are partnering with South Africa (Botswana, Ghana, Kenya, Madagascar, Mauritius, Mozambique, Namibia and Zambia) in order to develop strong radio astronomy communities in those countries.

SKA South Africa has also launched a Young Professionals Programme and a Bursary and Fellowship Programme, which are attracting young people to science and technology, and creating a critical mass of skills. This is not only beneficial to developing the knowledge economy, but also to future infrastructure development in South Africa, as well as across the entire African continent.

Members of the South African Academy of Engineering were captivated by Dr Fanaroff's presentation.

Dr Fanaroff provides some interesting statistics about the new radio telescope.

Faculty contributes to South Africa's first conduit hydropower facility

South Africa is facing an energy crisis that places additional importance on harvesting all available feasible sources of renewable energy. While the country is not particularly well endowed with conventional hydropower conditions, large quantities of raw and potable water are conveyed daily under either pressurised or gravity conditions over large distances and elevations.

The University of Pretoria, supported by the Water Research Commission (WRC) and other collaborating organisations, such as the City of Tshwane Metropolitan Municipality, Bloemwater and the eThekwini Municipality, has been engaged in a research project to investigate and demonstrate the potential of extracting the available energy from existing and newly installed water supply and distribution systems. The outcome of this project, led by Marco van Dijk of the Department of Civil Engineering, was the development of a counduit hydropower facility at Brandkop in the Free State.

The facility was unveiled on 31 March 2015. The Minister and Deputy Minister of Water and Sanitation, the Premier of the Free State, the Mayor of Bloemfontein, as well as other national, provincial and local dignitaries were invited to witness the unveiling.

The aim of the project was to enable the owners and administrators of bulk water supply and distribution systems to install small-scale hydropower systems to generate hydroelectricity for on-site use and, in some cases, to supply energy to isolated electricity demand clusters or even to the national electricity grid, depending on the location, type and size of the installation. It taps into an unutilised source of hydropower using excess energy in pressurised conduits to produce clean, renewable hydroelectric power. This type of energy generation (conduit hydro-power) is different to conventional hydropower generation where large dams are used to store river water in a reservoir. Its simplicity makes this solution so elegant because it harnesses energy that is already present within the existing water infrastructure. This energy would usually be lost in the presence of a pressure valve.

An initial scoping investigation by the WRC and the University of Pretoria highlighted the potential of hydropower generation at the inlets to storage reservoirs. In South Africa, 284 municipalities and several water supply utilities and mines own and operate water supply and distribution systems that could be considered for small-, micro- and pico-scale hydropower installations.

The application to install hydroelectric turbines in a water distribution system is fairly new in South Africa. Thus, three pilot plants were constructed to showcase several of the intricacies in the development process and to demonstrate the technologies. These sites included the City of Tshwane, the eThekwini Municipality and the Brandkop Reservoir in Bloemfontein. The research project indicated that it is feasible and technically possible to generate energy from water supply and distribution systems.

The WRC and Bloemwater then entered into a partnership to install the first full-scale demonstration unit for conduit hydropower in South Africa. This technology has proven to be a huge success in providing the main supply of energy for operating the Bloemwater Head Office in Pellisier. It can supply 96 kW/h of electricity from a pressurised conduit to power its operational facilities with a full capacity of 360 kW.

The Caledon-Bloemfontein potable water supply system supplies the majority of the water demand in Bloemfontein. The water is supplied to the Brandkop Reservoir, where the Bloemwater Head Office is located. Excess energy is dissipated through pressure control valves before being discharged into the reservoir. Approximately 30% of the water supplied via the Caledon-Bloemfontein pipeline is diverted through the turbine. The benefit of this hydropower-generating application is that minimal civil works are required. There are virtually no negative environmental or social effects that require mitigation and the anticipated lead times are short. Sufficient renewable energy is generated to supply the peak demand of Bloemwater's Head Office, as well as meeting the electricity requirements of the reservoir terrain. Approximately 800 MWh could be generated with this micro-hydropower installation annually.

The Minister of Water and Sanitation, Ms Nomvula Mokonyane, opens the flow to the turbine.

Site before construction.

Constructed turbine room.

Bypass pipework to the turbine.

DB and control panel.

Turbine, generator, control panel and regulators.

Completed turbine room.

The race to engineering excellence

The University of Pretoria annually presents Teaching Excellence and Innovation Laureate Awards to projects that display teaching practices that optimise teaching and learning, and contribute to best practice. Prof Tania Hanekom of the Department of Electrical, Electronic and Computer Engineering in the School of Engineering received this award in the individual category for her work in the Microcontrollers module (EMK 310) that is presented to third-year students in the Department of Electrical, Electronic and Computer Engineering.

The primary task of any engineer is to solve problems. The sole objective of the EMK 310 module is to equip third-year students with the problem-solving skills required to excel in an embedded systems-driven industry.

The EMK 310 module is hardware orientated. Although there is much focus on the development of firmware, assembly language is used as it is very close to the hardware of these devices. Further emphasis is placed on the peripheral circuits and systems that invariably form part of an embedded system. Starting microcontroller instruction with higher-level languages may potentially rob a student of the opportunity to become intimately familiar with the registers and structure of microcontrollers, which is crucial for an engineer to gain proficiency in these devices at all levels of complexity.

Evolution of the module

Prof Hanekom was assigned as assistant lecturer for EMK 310 in 2005. She had to attend to the practical section of the module. At that stage, lectures covered some basic aspects of microcontroller architecture and embedded design, while practical assignments focused on simple microcontroller implementations in assembly language without any formal guidance in assembly language programming. In addition, any programs that had to be written for tests were written on paper, which made grading ineffective and frequently inaccurate.

Over the last decade, the digital device market has exploded worldwide, driving a need for more engineering graduates equipped with embedded design skills than was the case a decade or two ago. It was clear from the start that it was necessary to redesign EMK 310 to address this need and empower students to excel in the embedded design industry.

Developing module content and presentation style

To align the content of the module with industry's expectations of the skills that graduate engineers should possess, the scope of the module was expanded to include design aspects that relate to interfacing a microcontroller system to the real world. This was done by including design strategies for various real-world interfaces as the main theoretical component of the module. Embedded design is no longer limited to computers, as was the case in previous years, but includes almost every technological innovation on the market.

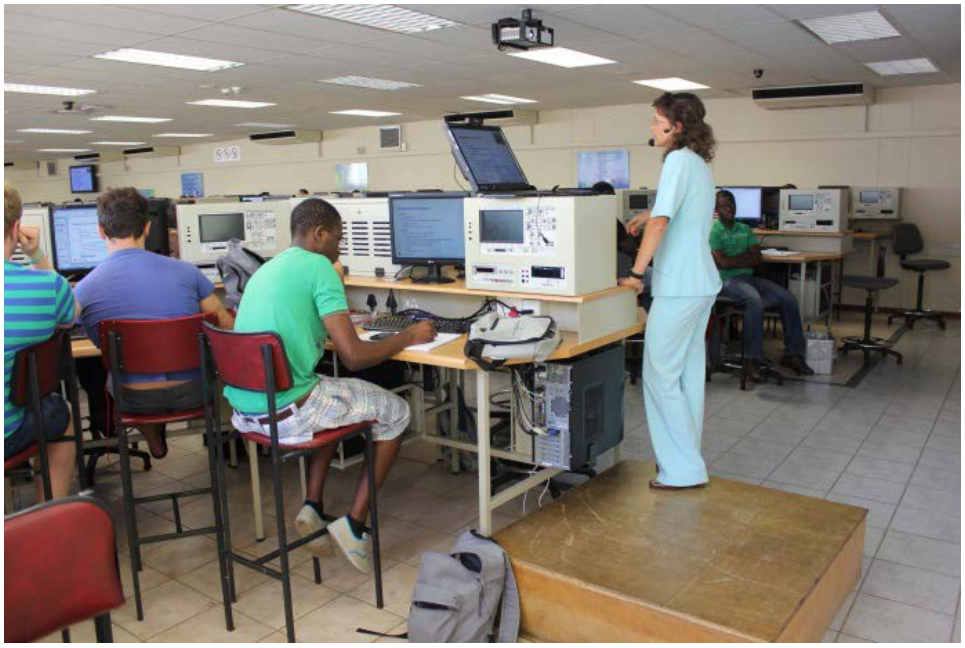
With the introduction of a stronger focus on the development of coding skills, the fact that students were left alone to master the programming component of the module necessitated intervention. The contact periods were divided into theory lectures, which covered design strategies, and application lectures that used assembly language as a vehicle to teach students the basics of microcontroller architecture and coding. These lectures made a remarkable difference to students' ability to apply theoretical skills in practical projects.

Setting up the infrastructure

Presenting a practical module to a large number of students generates a variety of infrastructure requirements. To facilitate a hands-on approach, a commercially available programmer was introduced as prescribed hardware for the module in 2006. The implication is that each student has his or her own hardware tool available, instead of having to share resources in the computer laboratories on campus.

Another requirement to facilitate a hands-on approach is the presentation of lectures in a computer laboratory where students may participate in interactive lectures. The capacity of the computer laboratory was expanded by installing two-way audio and video

Students had to master the programming component of the module.



Students follow the lecture in remote laboratories (top), while a multi-laboratory classroom setup shows the lecturer in the main laboratory (bottom).

links to two additional computer laboratories in a separate building. The lecture is presented in one of the laboratories and broadcast to two or three additional laboratories via an audio-visual link. Assistant lecturers act as proxy lecturers in the remote laboratories to manage questions through the audio-visual link to the lecturer in the main laboratory.

Innovations in the assessment strategy

Assessment of the theoretical aspects of the module is designed to be performed through objective assessment that includes the higher cognitive levels, such as design.

Although setting these tests is demanding, the time required for assessment is largely independent of the number of students, since the approach facilitates automated grading.

The assessment strategy for the coding section of the module had to be redesigned to allow students to access the tools that are available through the integrated development environment (IDE) and improve grading efficiency and accuracy.

Initially, the infrastructure was developed to allow the coding section of the module to be assessed by a computer-aided approach. Students had to complete the tests on a computer. They have all the documentation and software tools available that an engineer in industry would have, except internet access to prevent dishonesty.

This approach ensured that students' abilities could be tested in a simulated real-life environment, providing a more accurate assessment of their skills levels. Assessment could also be done with the debugging capabilities of the IDE software available to the examiner, which improved the quality of the grading substantially.

The coding section of the module is assessed by letting students write code to solve a practical engineering problem. Although a soft copy version of the solutions to these tests was uploaded, it took many hours to grade the tests. The increase in student numbers made the grading task almost impossible, given the time constraints.

In 2012, it was decided to start the development of automated grading software (AGS) that would grade the students' code answers. Grading time would become independent of student numbers, and post-test grading time would become negligible compared to the time it takes to grade tests manually. AGS was subsequently developed using the functionality of the Microchip MPLAB X SDK test bench.

This is possibly the only system in the world that grades assembler firmware tests using Microchip's MPLAB X SDK test bench, making it a novel teaching and learning tool.

Another feature that makes this tool unique is that it provides feedback to students through sectional and graded mark assignment.

Computerised tutoring system

One of the resources identified as a potential high-impact teaching tool is a computerised tutoring system (CTS), based on the AGS. Since tutoring large classes becomes increasingly difficult, a CTS is used to address common tutoring needs, which enables staff to focus on more specific tutoring needs.

The CTS has the ability to upload all previous tests to a server and gives students unlimited access to these tests. Students complete tests and submit them to a server that runs the AGS for the test. The students then receive feedback on their performance in the test. Students can resubmit a test as many times as they like. The AGS does not point out specific errors, but provides relatively detailed feedback on the location of the error in the code. Thus, it pinpoints the section in the code where marks are lost. The detailed feedback thus directs students to the sections in the code that they need to improve or correct. While the CTS will inherently encourage self-learning, its functionality could also include small-group access to encourage peer learning.

→ *Students prepare for the competition.*

Redesigning the practical assignments

It was necessary to change the students' perception of the module, as many students started dreading the module due to its high standard.

This was done by redesigning the practical component of the module. Students now design and build an autonomous line-following robot in teams and compete in a race at the end of the semester.

The design and construction of the autonomous robotic vehicle (ARV) is divided into three practical assignments. The objective is to progress through a number of manageable, structured phases and to provide an opportunity to assess, intervene, give feedback and encourage students throughout the project's development.

For each practical, there are four to five minimum requirements that need to be met to progress to the next practical. These minimum requirements reflect basic competency levels based on the industry's expectations, as well as the bare minimums to achieve a running ARV by the third practical.

The race

Race Day is the pinnacle of the EMK 310 programme and is organised to be a professional event that celebrates the students' achievements. In the three years that Race Day has been presented, the objective of changing students' perception of the module has been achieved. Students felt that they benefited from the module and deemed themselves equipped with the necessary skills to successfully attempt a project that requires embedded design.

Race Day also created the opportunity to involve a number of engineering companies. They could participate either through sponsorships or by attending Race Day.

Conclusion

The teaching philosophy for the module is centred around challenges and excellence. The development of this module not only challenged the students and fostered excellence, but also challenged the lecturer to develop a sustainable teaching and learning method.

The race to excellence is not won by setting a time measured in seconds, but in the development of skilled engineering graduates to support the technological endeavours of society. Being ready to face the starting line on Race Day at the end of a semester is a personal victory and a race won for every student who worked with the goal to succeed.

A comprehensive video and picture archive of Race Day events can be found on the website of the Department of Electrical, Electronic and Computer Engineering at www.up.ac.za/eece.

A decade of excellence in service-learning

The compulsory undergraduate Community-based Project (JCP) module for students in the Faculty of Engineering, Built Environment and Information Technology has become an institution at the University of Pretoria for the past 10 years.

The model, managed by Dr Martina Jordaan, received the Community Engagement Award of the University of Pretoria in 2015. It was also accredited by the Engineering Council of South Africa (ECSA) in 2006 and 2012, received an Education Innovation Award in 2006, was a finalist in the MacJannet Prize of the international Talloires Network in 2010 and won the Marketing, Advancement and Communication in Education (MACE) Excellence Award in the category Integrated Campaigns/Projects and the subcategory Social Responsibility and Citizen Development in 2014.

The JCP module requires students to dedicate 40 hours of their time to a community project that they plan and execute themselves. These are usually projects about which the students are passionate and in which they feel they can make a contribution in their personal capacities.

Involving students in community service gives them the opportunity to become aware of their social responsibilities as critical citizens and encourages them to use their knowledge and skills to improve the communities they serve.

A module such as this is an essential part of the curriculum of all undergraduate programmes in the Faculty, as it accommodates the need for community service and service-learning projects in a higher education environment.

Furthermore, the JCP module is ideally positioned to contribute towards achieving the outcomes of the University's strategic plan, which emphasises the importance of civic responsibility and citizenship.

The study programmes offered in the Faculty of Engineering, Built Environment and Information Technology at the University of Pretoria are highly technical and emphasise the development of technical skills. However, in the professional arena, graduates are required to interact with people who not only have different technical experience, but also come from various socio-economic backgrounds.

Dr Martina Jordaan

Students develop a sense of social responsibility, and an awareness of personal, social and cultural values.

As a service-learning effort, the JCP module is structured with the explicit goal of developing the soft skills that graduates from these technical programmes need when they enter the workplace. These include communication, interpersonal and leadership skills.

In the past decade, the Faculty has managed to produce more than 13 000 well-rounded graduates who possess the skills needed to make a meaningful contribution to society, not only during their time at university, but also during the course of their careers.

Dr Jordaan has been the primary contact person and lecturer for this module since its inception in 2005, and has dedicated many of her research efforts towards improving the processes and outcomes of the module.

Her research interests relate primarily to the practice of service-learning and community engagement, specifically

in disciplines related to engineering. With regard to the JCP module, Dr Jordaan has succeeded in setting this module aside from other service-learning modules not only by its scale, national impact and blended approach to learning and its ability to deal effectively with large student numbers, but also by its long-term impact on alumni of the Faculty.

Dr Jordaan conducted research among the 2005–2010 cohort of JCP students in order to establish the perceived value of the module for alumni, as well as enrolled students.

Enrolled students were requested to complete an online survey of their experience of the module at the end of their academic year, and the alumni were requested to complete the survey after having experienced distance and emotional growth. The participants in the study indicated that the module has been an important tool in raising awareness of their social responsibility. Enrolled students were positive about the role of the module in their curriculum, and the alumni indicated that the module had an impact on their decision to continue with community outreach projects after graduation.

In recent years, JCP alumni have decided to stay involved with their community projects, with the help of new JCP students. This becomes possible when students manage to develop a well-structured project with a high impact. Three of these projects have developed into true success stories.

Retang and the Siyaphila Youth Literacy Programme

Retang Phaahla studied BSc Quantity Surveying and is the founder and programme manager of the Siyaphila Youth Literacy Programme. She coordinates all programme activities and mobilises resources to enable operations.

Retang Phaahla, accompanied by some of the learners enrolled for the Siyaphila Youth Literacy Programme.

In 2013, Retang completed the JCP module and used it as a platform to start the Siyaphila Youth Literacy Programme, which tutors learners from Grade 6 to Grade 12 in Mathematics, Science and English. The programme not only tutors these learners, but also contributes to their holistic development. This is achieved with the programme's inclusion of life skills training and skills development.

The Siyaphila Youth Literacy Programme has grown over the past three years, and now has more than 157 learners enrolled in the Mamelodi project on the University of Pretoria's Mamelodi Campus. It has also launched a new project in Daveyton, where some 30 learners are already enrolled. Each year, new JCP students participate in the programme by providing tutoring services and playing a mentoring role. This supports the programme in its attempts to have a meaningful impact on the lives of the learners with which it interacts.

No act of kindness is ever wasted.

David and the SAAF Museum

David Bahaa Samuel Toma Ebeid is a mechanical engineer working at CHAERO Industries and is currently enrolled for his honours degree at the University of Pretoria. He has also completed his flight instructors' training, and works as a freelance commercial pilot. He first visited the South African Air Force (SAAF) Museum in 2009 as a first-year student to watch the annual air show. His official involvement with the museum commenced in 2010, while he was looking for a place to do an aeronautically based JCP project. For his JCP project that year, he and his team restored a World War II armoured car, and spent many hours on this project over three years.

Consequently, David has been identifying student projects that can be completed during the required JCP period in an attempt to help this museum, which lacks financial support and has minimal staff. He is a permanent volunteer at the SAAF Museum and currently supervises and manages the annual preparation of the display aircraft for the air show. Teams exceeding 50 students are brought in for their JCP module and David guides them through the process of completing their various projects. These include washing the planes or restoring the paint of the planes as a result of years of neglect and oxidation.

For the past four years, David has received the award for the best mentor of a JCP project.

A JCP group eagerly working on one of the planes at the SAAF Museum.

Samukelo and the MRYE project

Captain Samukelo Praise Vilakazi studied electronic engineering at the University of Pretoria, and is currently serving in the SAAF as a systems engineer in the Directorate: Combat Systems, where he works with Hawk and Gripen fighter aircraft and electronic warfare systems.

Samukelo serves as the chairman of the advisory board of the Mpepu Rural Youth Encouragement programme, affectionately known as MRYE, where he grooms and guides the current leadership of the programme.

MRYE was conceived from a discussion between Samukelo and Patience Maditsi, another engineering student.

They expressed their concerns about the fact that youth in rural areas do not have the same opportunities as youth from urban areas, and that this gap could be bridged with the right mentorship and encouragement.

Through the support of Prof Brenda Wingfield at the Centre of Excellence in Tree Health Biotechnology (CTHB), the first sponsored MRYE trip took place in 2006, and the programme has been a source of JCP projects ever since. Many students who participate in MRYE for their JCP projects go on to join the initiative for the duration of their studies.

MRYE with its sponsor, the CTHB, in November 2014.

The next generation of role models is born

Following up on the excellent tradition established 10 years ago, several exceptional community-based projects have recently been executed in the JCP module. During their involvement in these projects, students develop a sense of social responsibility, and understanding of social issues, and an awareness of personal, social and cultural values.

Future Families sieve project

Engineering students MJ Ferreira, Hendrik Maritz, Johan van Schalkwyk, Fritz Viljoen and Philipus Wessels assisted a local non-profit organisation, Future Families, to build a sieve for a compost project. One of the initiatives of this organisation is the Seboko Earthworm Casting project, which uses earthworms to break down waste products into fertilizer, which is then sold to create work for people living with HIV. After waste materials are broken down, they are put through a sieving process to separate the fine compost from stones, clods and sticks. In the past, sieving was done by casting the compost through a meshed plate that stood almost vertically. The students designed and built a rotary screen sieve, powered by an electrical motor, to accelerate the sieving process and increase the Seboko Earthworm Casting project's production and efficiency. Their YouTube video on the project was a finalist in the American Society of Engineering Education Community Engagement Division Film Festival.

Mapetla Hospice Day Care Centre project

Keneuoe Mokati and Tshepang Mashike renovated a playing area at the Mapetla Hospice Day Care Centre in Soweto by painting educational games on the pavement and walls. These renovations have the ability to teach the toddlers essential skills like counting and recognising shapes, and also brightens their environment and consequently lifts their spirits.

Be kind to every kind, not just mankind →

Wetnose project

Wihann Botha and André Matthee repaired a livestock trailer that was damaged and heavily rusted for the Wetnose Animal Rescue Centre. They removed the rust and damaged plates and replaced these so that the trailer could be used again safely. The community was very happy with the final product.

Lemur project

Two groups of students assisted the Bester Bird and Animal Zoo Park in Pretoria with projects for its ring-tailed lemur enclosures. The first group (comprising Gareth St Clair, Oliver Cribb, Hilton Gallagher, Tim de Mare and Henriette Schreiber) cleaned and restored an enclosure that had not been in use for many years, and improved the enclosure by constructing a wheelchair-friendly entrance. Many of the improvements were made by re-using some of the discarded features of the old enclosure. The second group (comprising Matthew de Kretser, Kaylan de Freitas, Timothy Lange and Greg Buchanan) covered the lemur interaction area with shade nets, erected perches and painted a mural on the back wall of the enclosure to make for a more interactive experience for visitors.

Timetable-generating software improves students' efficiency

The Faculty of Engineering, Built Environment and Information Technology at the University of Pretoria is proud to be the home of innovative young minds. Yi-Yu (Bruce) Liu, a third-year BCom (Informatics) student, along with his project team, has successfully developed groundbreaking timetable software for use by UP students and staff.

This software allows one to automatically customise one's university timetable, while being able to add additional information like test dates and personal events, from a single platform. The student team's Chylls Timetable Assistant has proven that dedication and creativity, along with an understanding of human needs, is the key to unlocking innovation in the field of informatics.

Bruce's goal has always been to inspire people. This mindset, along with his passion for developing technical skills in computer programming, has led him to pursue a career in informatics. Bruce experiences informatics as a study of people as much as it is a discipline dedicated to logical problem-solving. His combination of the soft skills needed for interacting with people, an understanding of business processes and the application of technical programming skills has led to the continuous development of this software.

Getting a good idea to become a workable project

The idea behind the Chylls Timetable Assistant originated from brainstorming sessions for undergraduate projects for which other ideas were pursued. However, with support from his colleague, Christopher Park, also a third-year BCom (Informatics) student, Bruce embarked on the process of turning this idea into a workable project. The two students teamed up to do the groundwork for the first version of the program, and during their university holiday, Bruce and Christopher approached both the Business Incubator at UP and Prof Alta van der Merwe, Head of the Department of Informatics, with a prototype of their software.

Prof Van der Merwe assisted the students to get their program onto the University's ClickUP system for students to start using. ClickUP is the University of Pretoria's centralised Blackboard e-learning system, to which all students and staff have access. At the beginning of an academic term, UP students and staff can download the Chylls Timetable Assistant software directly from the ClickUP home page.

In 2014, Chylls Timetable Assistant got some 5 000 clicks, and in 2015, this number has increased to some 9 000 clicks.

Bruce has been approached to present the program to first-year BCom (Informatics) students with the aim of not only boosting the user numbers for the Chylls Timetable Assistant, but also of inspiring them to work hard towards achieving great things while at UP.

The Chylls Timetable Assistant

The Chylls Timetable Assistant is linked to the University's database of information regarding academic modules, time slots, venues and test dates. What this means is that the program's database is automatically updated when the University's database is updated, eliminating the time-consuming process of manually updating datasets.

A user selects a Chylls Timetable template from a list provided. This includes the lecture timetables of the Faculty of Theology, the Groenkloof Campus, the Hatfield Campus, the Mamelodi Campus and the School of Engineering. The user then inputs his or her modules, specifying the language and period of presentation. The software has the ability to generate up to 30 000 colour-coded timetable options in under a minute, giving users the opportunity to plan their days much more efficiently. It also alerts users to subject clashes, which they can then attend to before registering for elective modules. This streamlines the process of generating individual timetables and allows for timetable optimisation in cases where the classes for one module can be attended at different times and in different groups.

The software code employs a true or false test that considers the

Informatics students Bruce Liu and Christopher Park turned an idea into a reality.

→ *The Chylls Timetable Assistant has proved an excellent tool to optimise the compilation of students' timetables.*

variables for each module in a recursive method. It incorporates a loop that goes through each module, puts everything onto the timetable and evaluates if each item can be seen as true (possible). Each variable that is not possible (either as a result of a clash or an alternative possibility) is marked as false and the system goes on to the next possibility. Users commend this by saying that it enables them to adapt their schedules to their needs; a frustrating and time-consuming thing to do by hand.

Technology always moves forward

If technology does not continue to develop, it stagnates; often unable to adhere to the changing needs of its consumers. In their second year, Bruce and Christopher were joined by other members of their class – Kristina Jovanovic (BCom (Informatics)), Duran Cole (BSc (IT) Software Development) and Nonde Masondo (BCom (Informatics)) – who assisted with interface redesigns and internal updates to improve the user experience of the program.

Most significantly, these improvements have been the program's ability to add test dates, times and venues, personal events and friends' timetables to a user's own timetable.

The program also has the ability to present summaries of modules and tests, generate reports and view maps of the various UP campuses. The new interface allows for complete customisation in terms of font and colour options for the timetable cells.

A significant requirement for the success of a new technology is its ability to integrate itself into the technologies that users already rely on. The Chylls Timetable Assistant can synchronise the timetable that it generates with a user's personal Google calendar – thereby using existing technology to improve user experience and adhere to user needs.

Prof Van der Merwe says that the Department of Informatics is proud of the students who were involved in the development of the Chylls Timetable Assistant software.

She believes they have gained valuable experience in the development and deployment of such a valuable system. Bruce expresses that he has learned that it is not enough to just develop a product. The process of getting users to interact with a new product is where more hard work starts. Networking and the promotion of a product that can improve people's lives is an essential step in the technology transfer process.

Furthermore, it is essential that a product – especially something as depersonalised as computer software – continuously allows for its own adaption to consumer needs.

Harold Abelson, founding director of both Creative Commons and the Free Software Foundation, said that programs must be written for people to read, and only incidentally for machines to execute. This is especially true when it comes to the field of informatics, where user needs dictate technical outputs.

The Chylls Timetable Assistant is compiled in such a way that future improvements in the form of added variables are possible as the need for these arise, enabling continuous innovation in this market.

BANKSETA awards bursary grants to Informatics students

→ *Forty Informatics students benefit from full-cost bursaries to the value of R5 million.*

On 25 August 2015, the University of Pretoria and BANKSETA signed a grant agreement that will provide full-cost bursaries to the value of R5 million to 40 South African students who require support to complete their 2015 academic year in the discipline of information technology.

The BCom (Informatics) degree at the University is the only degree of its kind in Africa that is accredited by the Accreditation Board for Engineering and Technology (ABET), a USA accreditation body that sets the global standard for study programmes in applied science, computing, engineering and engineering technology.

Prof Alta van der Merwe, Head of the Department of Informatics, says this grant addresses the national student funding crisis and is specifically aligned to the scarce and critical skills required by the inclusive banking sector, as well as the broader banking sector.

"We are very proud of this partnership with BANKSETA, as this grant is a great start to what we hope will be an ongoing relationship. Partnerships with the industry and sector education and training authorities (SETAs) are an ongoing focus of the University. We cannot address skills shortages in isolation."

This grant addresses the national student funding crisis.

The bursaries target second- and third-year BCom (Informatics) degree students who meet BANKSETA's minimum requirements.

The funding will go towards the students' registration, tuition and meal fees, as well as textbooks and technological devices (such as notebook computers).

One of the bursary recipients, Dorcas Kgonyane, says that the BANKSETA funding is not only a financial relief, but also an emotional relief.

He does not have to worry about his study debt when he finishes his degree and can launch his career with a clean slate.

Turning students into work-ready engineers

While engineers are generally rational and logical thinkers, immersed in the "hard" data of technology, who would rather not get involved with the intangible issues of human behaviour, they will inevitably end up spending nearly two-thirds of their time interacting with people.

This may be in the form of collaborating with other professionals, performing a project as a member of a team of engineers, managing staff or meeting with suppliers and service providers. It is therefore essential that they develop the soft skills required to deal with attitudes, perceptions, group norms and interpersonal conflict when they leave university and start working in industry. The ability to interact well with people is what distinguishes a highly effective engineer from a mundane one.

The Tuks Engineering Leadership Academy (TUKSELA) in the Department of Mining Engineering was established in 2013 to develop the soft skills that engineers require to function exceptionally in the world of work. While it was initially designed specifically for mining engineers, the programme is now available to students in all engineering disciplines.

The academy programme was initially launched with the support of Sasol, and entailed a multidisciplinary adaptation of the programme aimed specifically at Sasol bursary-holders. This was due to the experience of this company that newly graduated engineers were often in need of certain non-technical skills before they could function effectively in industry. A similar programme was presented to final-year mining engineering students of the University of Pretoria, with a focus on the dynamics of the mining industry.

The programme is aimed at equipping final-year students with basic leadership skills to supplement their technical education. The result is a well-rounded engineer, who can integrate interpersonal skills with technical know-how. As a result, prospective employers can be confident that a graduate from the University of Pretoria who has completed this programme will meet his or her expectations of employing a work-ready graduate.

The programme focuses on increasing the ability of graduates to adapt to the work environment and manage people issues that may affect their performance. According to Clive Knobbs, who heads up TUKSELA, "the programme will delve into the heart of the basic drivers of human behaviour and teach delegates to identify and manage the hidden dynamics of their own behaviour and that of others."

Knobbs is ideally suited to facilitate this programme, as his experience as former CEO and Chairman of Harmony Gold Mining Company (Pty) Ltd gives him insight into what the industry expects of graduates. His passion is to pass on his extensive experience in management and leadership to develop young undergraduate engineers, and to prepare them more adequately for the transition from student to employee.

The programme also utilises the expertise of Erna Gerryts, a registered educational psychologist. By applying three psychometric instruments, she focuses in the first instance on self- awareness, the core attribute in developing leadership. Emotional intelligence, which will enable young engineers to read the signs of intrapersonal and interpersonal constructs, is also exposed, revealing those constructs that promote or inhibit students' leadership approach. They are then encouraged and assisted to examine themselves in the fundamental areas of self-awareness, self-esteem and self-confidence in order to function more effectively in the workplace.

The programme provides an essential link between technical knowledge and the successful implementation of this knowledge through the association with people as individuals and in groups. It adds a dimension to the young engineer's toolbox, which is necessary when he or she is exposed to the rigours and reality of the workplace.

In 2015, 90 final-year engineering students took part in this programme, which entails eight modules presented over 50 contact hours (25 hours in the

classroom and 25 hours of experiential training in small groups with and without a facilitator as coach).

During the course of the programme, business-based case studies are used as examples on which role-playing exercises and simulations are based. Participants practise making presentations, engage in group work, learn interviewing techniques and perfect their communication skills.

There has been interest in this programme from other mining schools in Gauteng, as well as the Mining Qualifications Authority. Based on the positive feedback received from industry, TUKSELA was asked to present two comprehensive three-day leadership courses to 100 final-year engineering students at the University of Johannesburg earlier in 2015.

Following the initial sponsorship of the programme by Sasol, the programme is currently seeking an industry sponsor to ensure that it can continue to deliver effective, work-ready engineers to industry.

The impact of tyre diameter and surface conditions on the rolling resistance of mountain bikes

Prof Wynand Steyn and Janike Warnich

Cycling has been a mode of transportation since the first bicycle was invented in 1790. It became an organised sport in 1868. Four important components of a bicycle affect its performance when racing: frame mass, brakes, suspension and wheels.

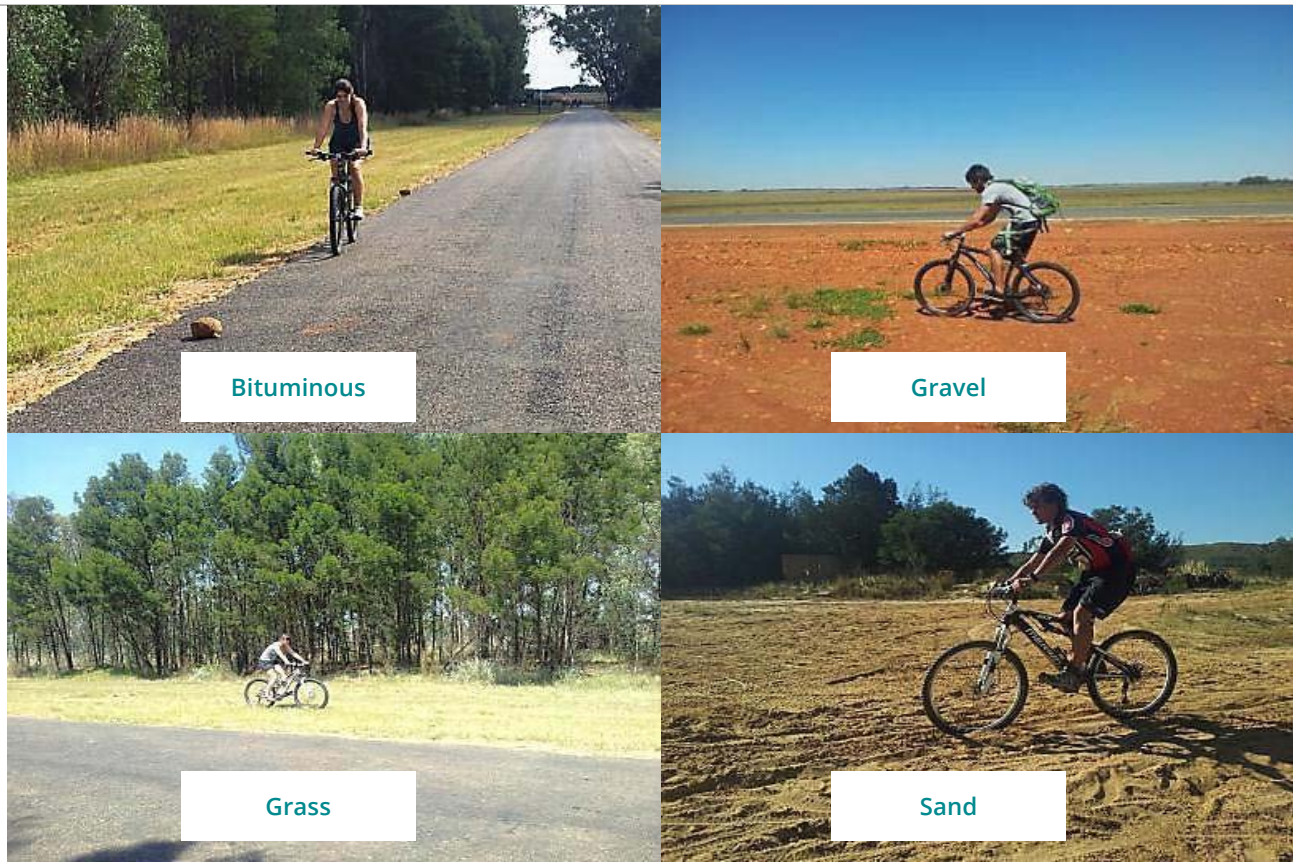
As the bicycle's design developed, the wheels evolved to the modern 26-inch wheels that most mountain bikes use today. A larger wheel, with a diameter of 29 inches, was developed for mountain bikes in the mid-1990s. This wheel diameter was deemed unsuccessful, until it was reintroduced in 2001. This raised a debate about the difference in speed and performance between 26-inch and 29-inch wheels (Herlihy, 2004). A study was conducted to determine how the rolling resistance of 26-inch wheels compares to that of 29-inch wheels in terms of a bicycle's performance. The five parameters that influence rolling resistance include surface, tyre inflation, cyclist mass, wheel diameter and suspension type.

Rolling resistance between the wheel and the road surface is a major factor in the performance of any vehicle. Rolling resistance is the reaction force acting on the bicycle due to the interaction between the tyre of the mountain bike and the surface of the terrain on which it is travelling. The interaction between the tyre and the terrain surface causes a loss of energy. By investigating the physics of this interaction, a better understanding of the performance efficiency of different wheel diameters will develop. The terrain surface has a major impact on the rolling speed of a wheel and the overall performance of the vehicle (Jackson, Willis, Arnold and Palmer, 2011). Grappe, Candau, Barbier, Hoffman, Belli and Rouillon (1999) found increased rolling resistance for bicycles with added mass and decreased rolling resistance for conditions of increased tyre inflation pressures. The key to reducing rolling resistance is to minimise the tyre casing deformation and, in so doing, minimise the loss of energy as a result of the interaction between the tyre and terrain.

Tyre inflation pressure affects the contact surface between the tyre and the ground. When the tyre is underinflated, the rolling resistance increases (Grappe et al., 1999). When the tyre is overinflated, it has poor grip due to the minimal contact surface, which will result in slippage. The slippage will render the brakes ineffective, especially during wet conditions. When comparing the difference between the deformation of the 26-inch and 29-inch wheels with the same tyre inflation pressure, it is evident that the larger wheel diameter suffers less deformation. This means that the 29-inch wheel should perform better than the 26-inch wheel.
The main cause of the loss of energy is the deformation of the tyre (depending on tyre properties), the deformation of the terrain surface (depending on terrain material properties) and the movement below the surface.

The following components directly affect the rolling resistance of a mountain bike (Schwalbe, 2011):

- The cyclist's mass affects the rolling resistance of the bicycle tyre. The cyclist's technique also contributes to the rolling resistance of the tyres in terms of



→ *The four surface types used in the experiment*

how mass is distributed while riding. The bicycle's suspension will determine whether or not the vertical load on the tyre will fluctuate. The change in the combined rolling resistance of both tyres depends on the cyclist's technique.

- The tyre consists of four major components that influence the performance of the entire bicycle: width, tread pattern, tread count and tyre inflation pressure. The quality of any of the components of the wheel affects the performance and durability of the wheel.
- Suspension ensures that less vertical mass fluctuation is transferred to the tyres, decreasing tyre deformation. Mountain bike suspensions can be divided into three types: rigid, hard tail and full suspension. Rigid bicycles have no suspension and are not very common in mountain biking. A hard tail only has suspension at the front fork, and coil or air-compressed shocks absorb the impact. A full suspension bike has suspension on the front fork and rear stays.
- The terrain surface influences rolling resistance. Four surfaces were used to determine the effect of rolling resistance on the performance of 26-inch and 29-inch wheels. These are bituminous, gravel, grass and sand.

The difference between the rolling resistance of the two wheel diameters was tested.

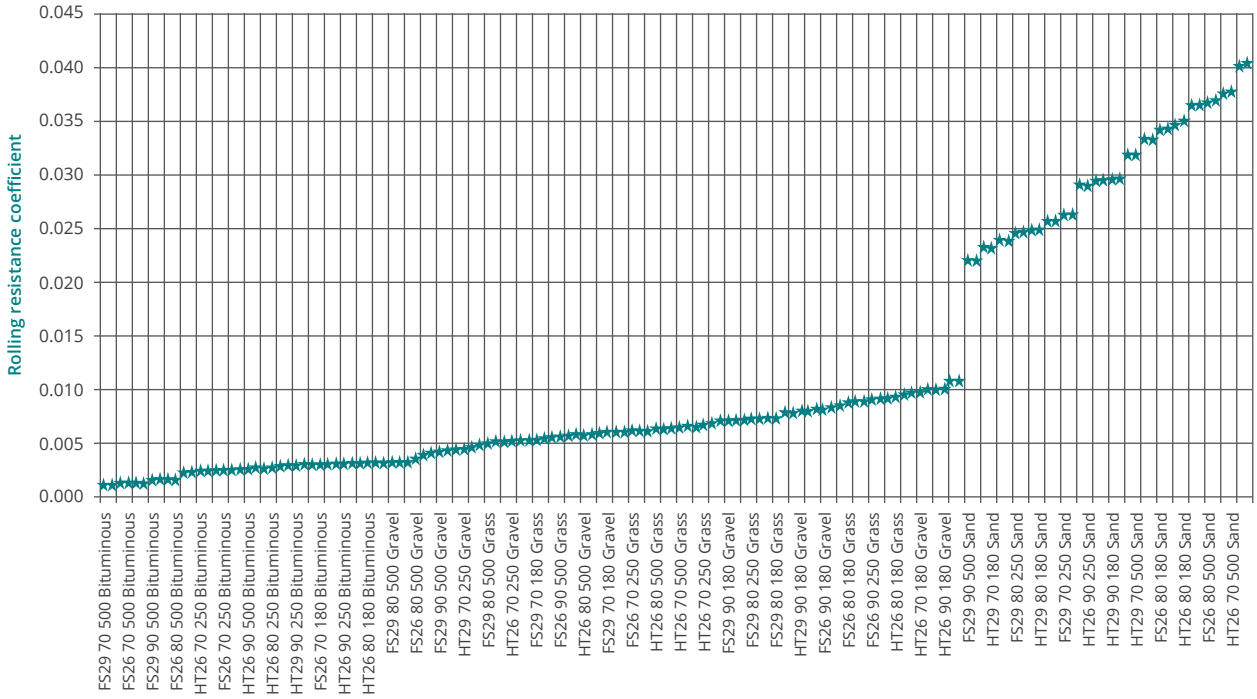
The difference between the rolling resistance of the two wheel diameters was tested. The experiment was conducted on four different terrain surfaces.

The difference in the effect of the masses of three different cyclists on rolling resistance was tested. The masses of the three cyclists were adjusted by weights to represent masses of 70 kg, 80 kg and 90 kg respectively. The cyclists accelerated to 15 km/h to incorporate some air resistance in the measurements and calculations. Four mountain bikes were used in the experiment: a 26-inch hard tail (HT26), a 26-inch full suspension (FS26), a 29-inch hard tail (HT29) and a 29-inch full suspension (FS29) (Figure 1).

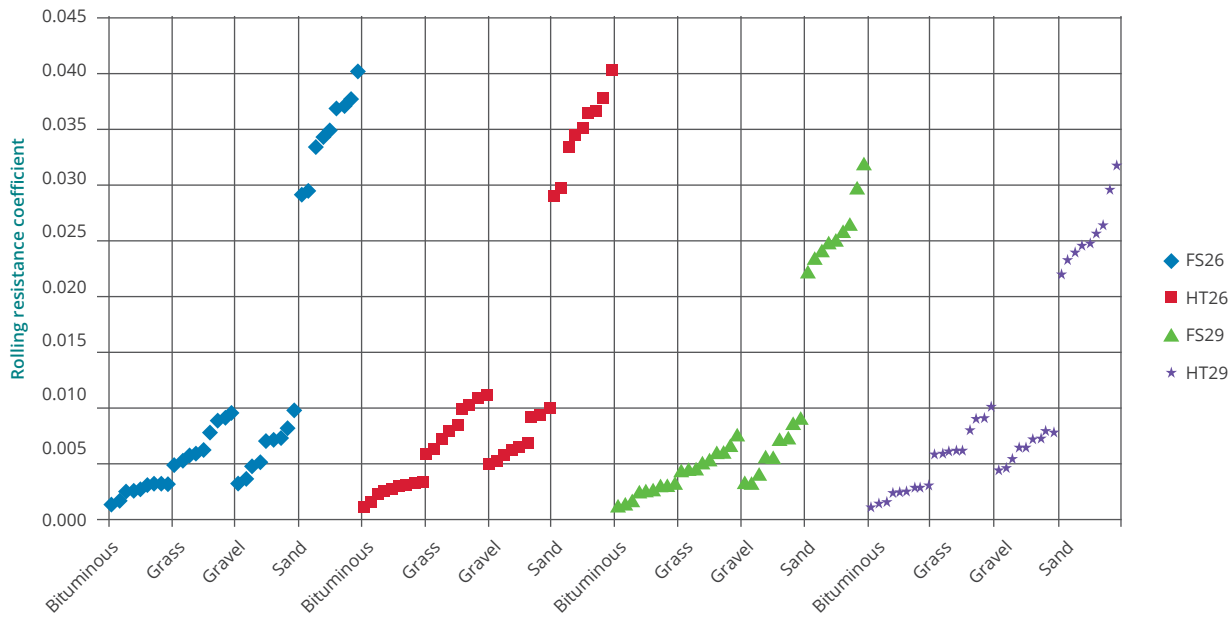
The experiment was conducted using the same four terrain surfaces, the same two wheel diameters, different tyre inflation pressures and the different masses of the same three cyclists. The difference between the effect of different tyre inflation

pressures on rolling resistance was tested, as was the difference between the effect of two different suspensions on rolling resistance. The difference between the effect of the two wheel diameters with an obstruction on the terrain surface on rolling resistance was also tested. The test was conducted on the gravel surface with the same two wheel diameters at two different tyre inflation pressures with the different masses of the same three cyclists. The difference between the rolling resistances measured when rolling over an obstruction, as well as the rolling resistances of the corresponding terrain surfaces and wheel diameters previously measured, was calculated. These differences are the preservation of the momentum of each wheel diameter in terms of rolling resistance force.

The data was separately analysed for each of the different parameters, based on the average rolling resistance coefficients calculated for each of the various parameters.



→ *Figure 1: Rolling resistance coefficients measured for all four types of bicycle, cyclist masses, wheel diameters, tyre inflation pressures and surfaces.*



→ *Figure 2: Measured rolling resistance for four mountain bikes indicating the effects of wheel diameter and suspension type.*

A summary of the average, standard deviation and coefficient of variation of the rolling resistance coefficients calculated for the five main parameters investigated in this research study are provided in Table 1.

The average rolling resistance of the 26-inch diameter wheel was higher than that of the 29-inch diameter wheel. The data indicates that the 26-inch wheel diameter (both suspension types) has a higher rolling resistance for the sand, grass and gravel surfaces. For the bituminous surface, the differences were negligible. The data thus indicates that the 29-inch wheel diameter should be beneficial when riding on off-road surfaces, but on paved surfaces, the benefit will be negligible.

The terrain surface showed the largest effect on rolling resistance.

An analysis of the data in Table 1 and Figure 1 indicates that the bituminous surface had the lowest average rolling resistance coefficients, followed by the grass and gravel surfaces with similar values, and the sand surface with the highest average rolling resistance coefficient, a factor of between 4.5 and 15 times higher than the other three surfaces.

The data in Table 1 and Figure 2 indicates that higher tyre inflation pressure causes lower rolling resistance. This agrees with published data (Grappe et al., 1999). The data in Table 1 is based on three repeats of each measurement.

The average rolling resistance coefficient was not affected to the same degree by cyclist mass as it was by the tyre inflation pressure and surface type. Although a general increasing rolling resistance coefficient trend is visible as the cyclist's mass increases, it does not constitute a major increase. Therefore, cyclist mass appears to have a secondary effect on rolling resistance.

Data from Figure 2 indicates that, in terms of rolling resistance and the four surfaces evaluated, there is no measurable advantage in using full suspension, as opposed to hard tail suspension.

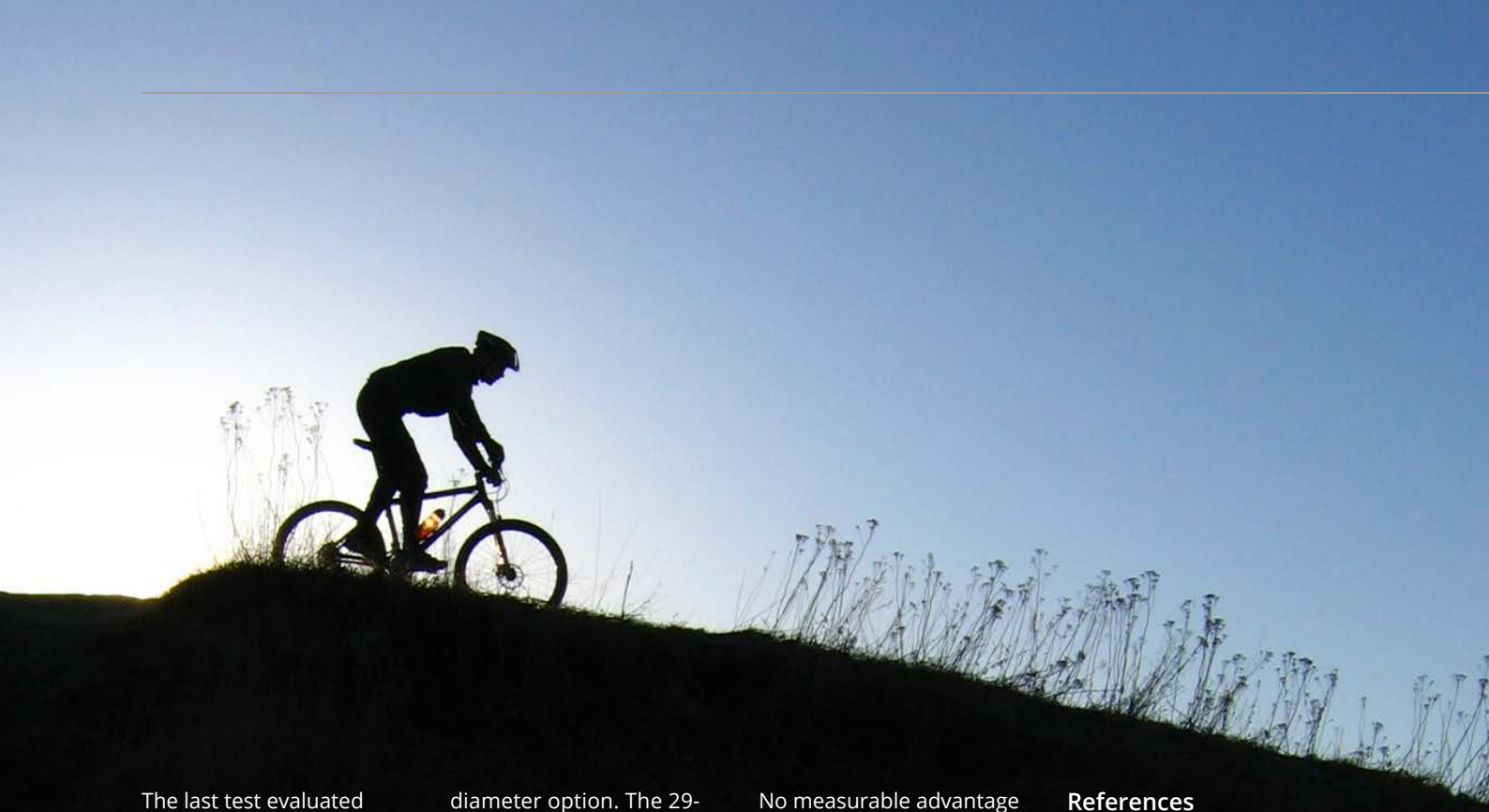
When evaluating the average rolling resistance ranges for all five parameters, the terrain surface showed the largest effect on rolling resistance, followed by wheel diameter and tyre inflation pressure. Both the cyclist mass and the suspension type showed only secondary effects on rolling resistance. This may be partly attributed to the relatively small difference in the cyclists' masses in the experiment.

→ *Table 1: Average and standard deviation of rolling resistance coefficients calculated for the five main parameters*

	Average rolling resistance coefficient	Standard deviation rolling resistance coefficient	Coefficient of variation [%]
Surface			
Bituminous	0.002	0.001	29%
Grass	0.007	0.002	23%
Gravel	0.006	0.002	33%
Sand	0.030	0.006	18%
Tyre inflation pressure			
180 kPa	0.012	0.011	91%
250 kPa	0.012	0.011	94%
500 kPa	0.011	0.012	114%
Cyclist mass			
70 kg	0.011	0.012	107%
80 kg	0.012	0.011	98%
90 kg	0.012	0.011	93%
Wheel diameter			
26-inch	0.013	0.013	100%
29-inch	0.010	0.009	93%
Suspension type			
Hard tail	0.011	0.012	103%
Full suspension	0.012	0.011	95%

→ *Table 2: Percentage shorter distance travelled after the obstacle was introduced*

Tyre inflation pressure	500 kPa			250 kPa		
Cyclist mass	**70 kg**	**80 kg**	**90 kg**	**70 kg**	**80 kg**	**90 kg**
HT26	10%	12%	16%	19%	23%	28%
FS26	6%	8%	14%	14%	16%	20%
HT29	5%	5%	6%	7%	11%	16%
FS29	2%	3%	5%	6%	8%	10%



The last test evaluated the effect of an obstacle (a rock 100 mm in height) that the mountain bike had to negotiate during a typical coast-down test on the distance before the mountain bike came to a standstill. The objective was to determine to what extent a typical obstacle will affect the cyclist's momentum. The shorter distance that each of the mountain bikes travelled after traversing the obstacle is shown as a percentage in Table 2. Higher values indicate that the mountain bike came to a standstill a shorter distance after the obstacle (greater loss of momentum) than for lower values, with a 100% value indicating that the mountain bike stopped at the obstacle. The obstacle test was only conducted on the bituminous surface.

An analysis of the data in Table 2 indicates that the best combination for maintaining momentum after traversing over an obstacle is high tyre inflation pressure, low cyclist mass and the full suspension 29-inch wheel diameter option. The 29-inch wheel diameter has an advantage over the 26-inch wheel diameter, with even the low tyre inflation pressure hard tail 29-inch mountain bike being on par with the high tyre inflation pressure full suspension 26-inch mountain bike.

Conclusion

The 26-inch wheel diameter (both suspension types) has a higher rolling resistance than the 29-inch wheel diameter for the sand, grass and gravel surfaces, with the bituminous surface showing negligible differences.

The sand surface has a rolling resistance coefficient factor of between 4.5 and 15 times higher than the gravel, grass and bituminous surfaces. Terrain surface was shown to have the largest effect on the rolling resistance coefficients of the evaluated parameters, followed by cyclist mass and wheel diameter, and finally tyre inflation pressure.

No measurable advantage could be identified for using a full suspension as opposed to a hard tail suspension in terms of rolling resistance on the four surfaces evaluated. The best combination for maintaining momentum after traversing an obstacle is the high tyre inflation pressure, low cyclist mass and full suspension 29-inch wheel diameter option.

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The heat transfer and thermodynamic performance of a parabolic trough receiver with perforated plate inserts

Aggrey Mwesigye, Prof Tunde Bello-Ochende and Prof Josua Meyer

Parabolic trough solar collectors are one of the most technically and commercially developed of the available concentrated solar power technologies. The parabolic trough's linear receiver is a central component to the performance of the entire collector system. Its state and design greatly affect the performance of the entire collector system.

The receiver's performance is significantly affected by the thermal loss and heat transfer from the absorber tube to the working (heat transfer) fluid. The conventional receiver consists of an evacuated glass envelope to minimise the convection heat loss and a selectively coated absorber tube to minimise the radiation heat loss. Numerous studies have been carried out to characterise the thermal performance of the receiver and to determine the thermal loss at different receiver conditions (Burkholder and Kutscher, 2008; Burkholder and Kutscher, 2009; Lüpfert, Riffelmann, Price, Burkholder and Moss, 2008; Dudley, Kolb, Mahoney, Mancini, Sloan and Kearney, 1994; Dudley, Evans and Mathews, 1995; Padilla, Demirkaya, Goswami, Stefanakos and Rahman, 2011). From these studies, it has been shown that receiver thermal loss depends largely on the state of the annulus space between the glass cover and the absorber tube itself, its selective coating and temperature, the wind speed and the heat transfer from the absorber tube to the heat transfer fluid.

The presence of circumferential temperature gradients in the receiver's absorber tube is a major concern.

The researchers considered a simplified model of the parabolic trough receiver.

At low flow rates, higher temperature gradients in the tube's circumference can cause bending of the tube so that the glass cover will eventually break (Almanza, Lentz and Jiménez, 1998; Muñoz and Abánades, 2011). The peak temperature in the absorber tube facilitates degradation of the heat transfer fluid, as these temperatures increase above 673.15 Kelvin (K) (Moens and Blake, 2010; Li, Wang, Lei and Li, 2012). The degradation of the heat transfer fluid results in hydrogen permeation in the receiver's annulus. With formation of hydrogen in the receiver's annulus, its thermal loss increases significantly, which affects the collector's thermal performance (Forristall, 2003).

Most failures of parabolic trough receivers, especially the breakage of the glass cover, have been attributed to the circumferential temperature gradients in the absorber tube. Therefore, reducing these temperature gradients and temperature peaks can increase the life span of the receiver and prevent thermal loss due to vacuum loss and hydrogen permeation in the receiver's annulus space. The maximum temperature gradient for the safe operation of receiver tubes is about 50 K (Wang, Liu and Xu, 2013).

The enhancement of convective heat transfer in the receiver's absorber tube is one of the relevant solutions to the above concerns. With improved convective heat transfer in the absorber tube, circumferential temperature gradients and peak temperatures in the absorber tube can be reduced and risks of breakage and hydrogen formation can be minimised. As such, heat transfer enhancement in the receiver's absorber tube has received considerable attention in the recent past. Ravi Kumar and Reddy (2008) numerically analysed a receiver with various porous fin geometries and compared its performance to that of a receiver with longitudinal fins.

Ravi Kumar and Reddy (2009) also investigated the performance of the receiver with a porous disc at different angles of orientation, different heights and different distances between the consecutive discs.

Muñoz and Abánades (2011) analysed an internally helically finned absorber tube with a view to improving thermal performance and minimising the temperature gradients in the absorber tube. The absorber tube temperature difference was reduced by between 15.3 and 40.9%.

All these studies used an approximate heat flux boundary condition on the receiver's absorber tube. The use of a realistic non-uniform heat flux boundary condition is crucial in determining the temperature gradients, peak temperatures and entropy generation rates in the receiver.

Recently, Cheng, He and Cui (2012) analysed the heat transfer enhancement of a parabolic trough receiver using unilateral longitudinal vortex generators with a realistic non-uniform heat flux boundary condition. The wall temperatures and thermal loss were found to decrease with each geometrical parameter considered. Wang et al. (2013) investigated heat transfer enhancement using metal foams in a parabolic trough receiver for direct steam generation using realistic non-uniform heat flux boundary conditions. The maximum circumferential temperature difference was shown to drop by 45%.

Only a few investigations have been made of the effect of heat transfer enhancement on the thermodynamic performance of enhanced devices. Therefore, in this research study, a numerical investigation was carried out of the heat transfer, fluid friction and thermodynamic performance of a receiver with centrally placed perforated plates. The plates were centrally placed to provide heat transfer enhancement in the core flow, thereby avoiding any possible hot spots that can facilitate the degradation of the heat transfer fluid, which are characteristic of heat transfer enhancement methods with recirculation, separation and re-attachment. In addition to heat transfer performance, using the entropy generation minimisation method, the effect of heat transfer enhancement on the thermodynamic performance of the receiver is also investigated and presented. This study presents an investigation of the thermal and thermodynamic performance of a receiver for a parabolic trough solar collector with perforated plate inserts.

The perforated plate assembly is considered to be supported on a thin, axially placed rod as shown in Figure 1(a). The placement of the perforated plate is defined by the spacing between the two consecutive plates (*p*), the diameter of the plate (*d*) and the angle of orientation measured from the positive y-axis (*β*). *β* is negative in the clockwise direction and positive in the anti-clockwise direction.

In their analysis, the researchers considered a simplified model of the parabolic trough receiver in which the effect of the central rod and other supports is considered negligible. Further still, the flow was found to be periodically fully developed after about five perforated plate inserts, regardless of the spacing. Therefore, for this analysis, a periodic module of the receiver's absorber tube was considered, as shown in Figure 1(c).

Similar to actual receivers, the space between the absorber tube and the glass cover is considered evacuated to very low vacuum pressures (0.013 Pa) so that only radiation heat loss takes place. The receiver tube that was used is similar to the SEGS LS-2 receiver.

The receiver parameters used are shown in Table 1. Due to the symmetrical nature of the model, only half of the receiver tube was considered in this analysis. The parameters used in this study for the reflector, receiver and perforated plate inserts are given in Table 1.

Governing equations

For the range of Reynolds numbers considered, the flow is in the fully developed turbulent regime. As such, the governing equations used in this analysis for steady-state and three-dimensional turbulent flow are the continuity, momentum and energy equations given.

The study aimed to investigate the thermal, fluid friction and thermodynamic

→ *Table 1: Geometrical and optical values of the parabolic trough collector*

Reflector		Receiver		Perforated plate	
a_c	6.0 m	d_{ri}	0.066 m	β	-30–30°
L_c	7.8 m	d_{ro}	0.07 m	d	0.03–0.06 m
ρ	0.96	τ_g	0.97	p	0.04–0.20 m
σ_c	0.0002mrad	α_{abs}	0.96		

→ *Equations*

Continuity

$$\frac{\partial(\rho u_i)}{\partial x_i}=0 \tag{1}$$

Momentum equation

$$\frac{\partial}{\partial x_j}(\rho u_i u_j)=-\frac{\partial P}{\partial x_i}+\frac{\partial}{\partial x_j}\left[\mu_{eff}\left(\frac{\partial u_i}{\partial x_j}+\frac{\partial u_j}{\partial x_i}\right)-\frac{2}{3}\mu_{eff}\frac{\partial u_i}{\partial x_i}\delta_{ij}-\rho\overline{u_i'u_j'}\right]+S_m \tag{2}$$

Energy equation

$$\frac{\partial}{\partial x_j}(\rho u_j c_p T)=\frac{\partial}{\partial x_j}\left(\lambda\frac{\partial T}{\partial x_j}+\frac{\mu_t}{\sigma_{h,t}}\frac{\partial(c_p T)}{\partial x_j}\right)+u_j\frac{\partial P}{\partial x_j}+\left[\mu_{eff}\left(\frac{\partial u_i}{\partial x_j}+\frac{\partial u_j}{\partial x_i}\right)-\frac{2}{3}\mu_{eff}\frac{\partial u_i}{\partial x_i}\delta_{ij}-\rho\overline{u_i'u_j'}\right]\frac{\partial u_i}{\partial x_j} \tag{3}$$

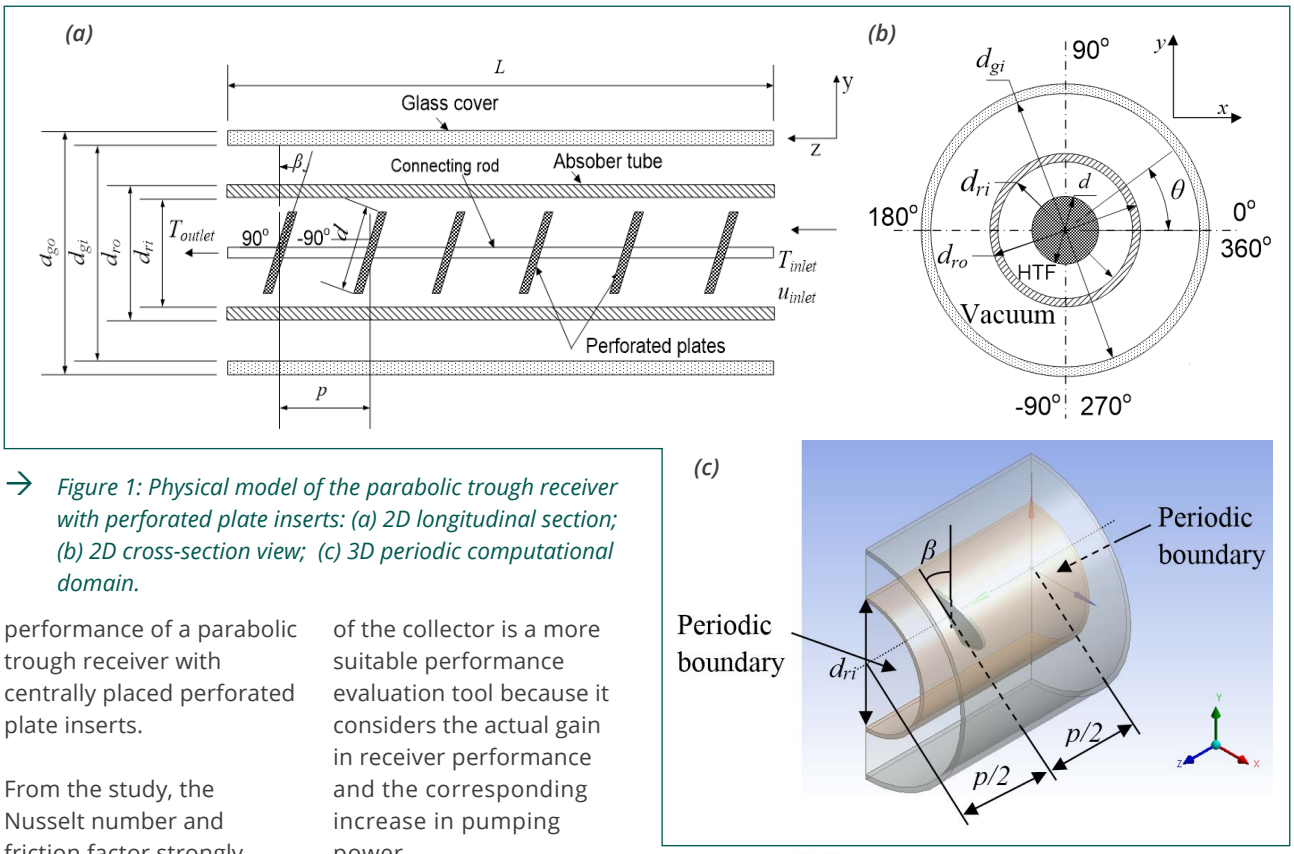

Figure 1: Physical model of the parabolic trough receiver with perforated plate inserts: (a) 2D longitudinal section; (b) 2D cross-section view; (c) 3D periodic computational domain.

performance of a parabolic trough receiver with centrally placed perforated plate inserts.

From the study, the Nusselt number and friction factor strongly depend on the spacing and size of the insert, as well as flow Reynolds number. For the range of Reynolds numbers, temperatures and geometrical parameters considered, the Nusselt number increases about 8 to 133.5% with friction factor penalties in the range of 1.40 to 95 times compared to a receiver with a plain absorber tube, while the thermal enhancement factors are in the range of 0.44 to 1.05%.

The use of thermal enhancement factors for performance evaluation was shown to be unsuitable for the evaluation of the enhanced parabolic trough receivers.

It does not consider the increase in performance from reduced receiver losses due to lower emissivity and lower absorber tube temperatures. The modified thermal efficiency of the collector is a more suitable performance evaluation tool because it considers the actual gain in receiver performance and the corresponding increase in pumping power.

The use of perforated plate inserts is shown to increase the modified thermal efficiency of the receiver in the range 1.2 to 8%, depending on the insert spacing, insert size and Reynolds number. The modified thermal efficiency increases in the range of 3 to 8% for insert spacing ranging from $0.08 \leq \tilde{p} \leq 0.20$ and insert size in the range $0.45 \leq \tilde{d} \leq 0.61$ for flow rates lower than 37 m^3 per hour at all inlet temperatures. This flow rate corresponds to the following mass flow rates evaluated at different temperatures: 8.61 kg/s at 400 K, 7.66 kg/s at 500 K, 6.56 kg/s at 600 K and 5.92 kg/s at 650 K.

Significant reductions in absorber tube temperature gradients and peak temperatures were achieved. The maximum reduction in absorber tube temperature gradients was about 67%.

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Prof Tunde Bello-Ochende *is an Associate Professor of Mechanical Engineering at the University of Cape Town. His research interests include theoretical, experimental and numerical optimisation of heat transfer devices from macro to micro scales.*

Prof Josua Meyer *is Head of the Department of Mechanical and Aeronautical Engineering at the University of Pretoria. He is also the Chairperson of the School of Engineering and is an NRF-rated researcher.*

→ *Techniques to maximise the utilisation of solar power are essential to curb the energy crisis.*

As far as safety of the tube is concerned, the reduction in the absorber tube's temperature gradients is beneficial for applications requiring low flow rates where temperature gradients are higher than 50 K.

A reduction in absorber tube temperatures also plays a significant role in reducing radiation losses. Thus, reducing temperature gradients to values lower than 50 K will further improve the performance of the receiver, provided the gained performance is not less than the increase in pumping power.

The use of inserts is also shown to improve the thermodynamic performance of the receiver by minimising the entropy generation rates below a given flow rate. Overall, volumetric flow rates lower than 43.4 m^3 per hour were found to give entropy generation rates lower than those of a receiver with a plain absorber tube for all perforated plate geometrical parameters and temperatures considered.

The maximum reduction in the entropy generation rate was about 52.7%.

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The defining role of organisational culture in managing services-related moments of truth

Dr Richard Weeks

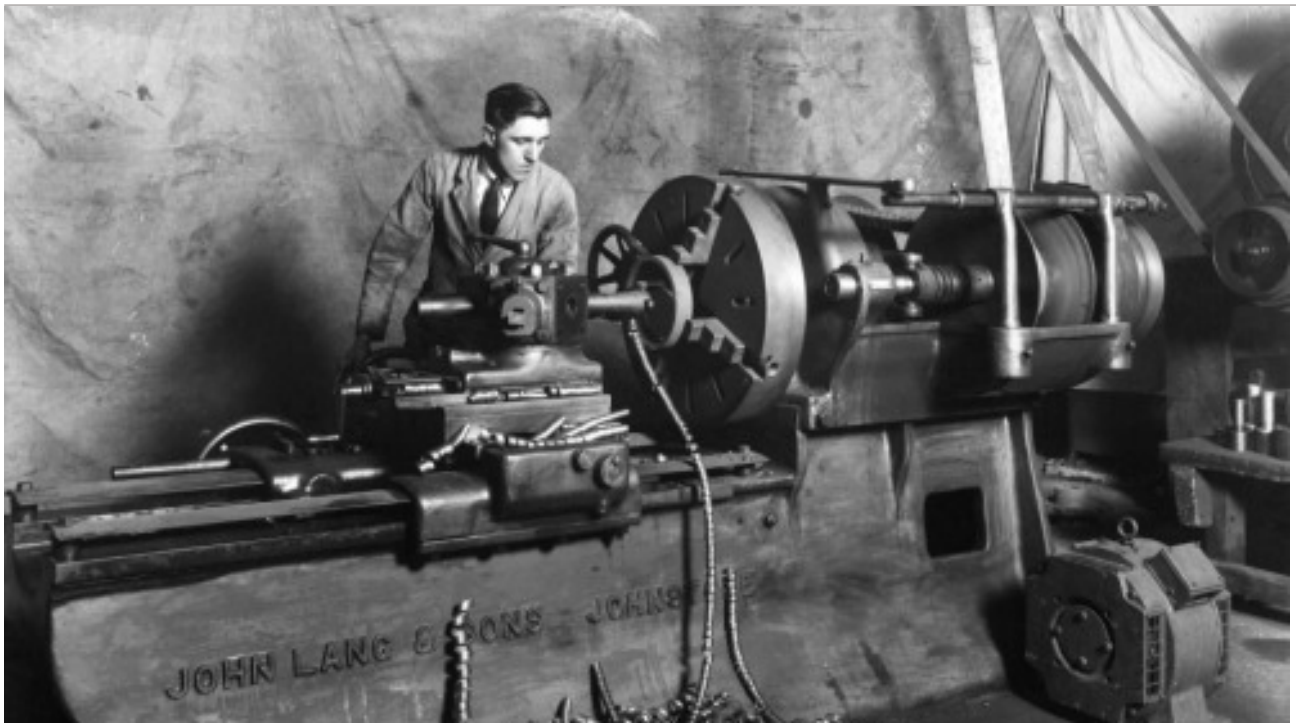
An archaic picture of engineers and technologists as machine-driven, technology-based individuals underpins the traditional mechanistic paradigm of engineering. This has resulted in a deterministic management approach that assumes a sense of predictability of which the underlying logic is reductionism.

A more contemporary reality is one of engineers being engaged in a host of moments of truth, which include brief encounters with clients, both internal and external to the enterprise. Nowhere is this more pertinently portrayed than within their contemporary consultancy and project management services activities. Each of these encounters tends to be emergent, with little predictability of the precise outcome. With a host of encounters and moments of truth taking place within engineering enterprises, it is difficult to see how they can be successfully managed. Effectively, service provider and client are co-instrumental in determining the service outcome, which adds to the situation's complexity.

Snowden and Boone (2007) caution that "leaders who try to impose order in a complex context will fail," yet in practice the traditional trend is precisely that: attempting to predetermine the behaviour patterns of the people within the service encounter. Many engineering institutions have compiled a values statement as part of their mission statement. This statement emphasises the desired behavioural attributes, such as trust, quality, honesty, service excellence, accountability, integrity and client orientation, all directed at attempting to act as an unseen hand shaping staff behaviour patterns. These statements often remain "hidden hands" of good intent. Even a brief review of client complaints lodged on the Hello Peter website reveals that many institutions' "hidden hands" are not engendering service excellence from a client perspective. Poor service delivery appears to be a recurrent theme within the media, particularly in relation to public-sector institutions that are providing critical community services, such as healthcare, roads, transportation, electricity, water and refuse removal. It needs to be investigated why the virtuous intent of these values statements seldom manifest in practice, while the literature seems to advocate the importance of compiling a values statement as part of the institution's mission and business philosophy.

The defining role of organisational culture as a perceptual and behavioural determinant is well established in the existing management literature. However, how the desired cultural attributes manifest in the day-to-day service delivery operations of front-stage services, which render staff and back-stage support teams, are not well articulated. Within the traditional management literature, the dominant view is one of actively and intentionally managing the concept to realise a desired or envisioned culture, although it is also acknowledged that this is extremely difficult to achieve. A more contemporary interpretation within the literature is depicted by Lissack (1999), who states that complexity theory challenges traditional management practice by noting that human activity accommodates the possibility of emergent behaviour. The perception of culture as a naturally evolving living system is therefore implied or is the active patterning of people's interaction with their environment.

A complex adaptive view of culture as emerging patterns implies that management would need to identify emerging patterns that are favourable and patterns that will hinder effective service encounters. Favourable patterns need to be stabilised, while those hindering the process need to be disrupted. With this in mind, the assertion that culture is constantly evolving and travels along an infinite continuum in a harmonious learning environment is particularly significant. This environment is one characterised by staff engaging in rituals, passing along corporate myths and stories, and the use of arcane jargon. The insinuation is one of culture constantly evolving as employees and clients interact, and new values, beliefs and similar cultural attributes emerge in the process. Context plays a significant role in the emerging moment of truth;



→ *Project management has come a long way since the early days.*

servicescapes, emotions and expressed feelings can either facilitate or hinder the service encounter. The emergence of the service encounter is accompanied by many stories conveyed by word of mouth, which influences the perception of an institution's service delivery. Future clients' expectations can, in fact, be shaped by these narrative accounts that are relayed along a host of interacting communication networks. There is also the danger of these narratives being distorted along the way.

Clients' expectations and their interpretation of the service experience against these expectations are really the two key determinants in defining service quality from a client's perspective. Managing these determinants is extremely complex and, at best, institutions can attempt to shape the variables involved: a central tenet being the service provider's staff behaviour that has a ripple effect in terms of the word-of-mouth conveyance of narratives. The nurturing of a services culture can play a crucial role in this regard.

Nurturing a service-directed culture

In the context of the service encounter, behavioural patterns are directed at building positive relationships with clients, a skill built on mutual respect and a service ethic, effectively combining service-related skills and culture as a behavioural determinant. Undoubtedly, this is inculcating a services mindset, a way of thinking or a world view that places client needs and expectations at the core of the institutional business model. The problem with this, however, is that traditional management practice is directed at standardisation, whereas more likely than not, client needs and expectations could differ quite substantially. An important point of departure in initiating the service encounter is determining the client's needs and expectations and how these can be met through mutual discussion, while building a solid relationship with the client. This requires a host of skills that include dealing with clients' emotional responses, past service experiences and present situations. Underlying cultural attributes, such as empathy, concern and a sense of sensitivity in conducting the service encounter, are instrumental in shaping the less tangible elements of the servicescape.

This special blend of service-related skills and cultural determinants needs to become part of the institutional DNA, something that will not take place overnight. It is argued that they emerge as part of a determined and sustained process that emphasises the institution's commitment to the rendering of quality services to clients. Part of the process entails monitoring emerging services patterns, both success and failure, and reinforcing positive, while disrupting negative emergent patterns. This process differs quite substantially from the standardisation paradigm of a mechanistic era.

Complex, evolving service-based cultures are best understood as dynamic networks of interactions and relationships that are based on a shared understanding of desired cultural attributes that are expressed during the moments of truth. It entails the need for employee empowerment within set boundaries and the engendering of a sense of trust and responsibility. It is implied that the services culture will emerge through the social interaction and dialogue within an enterprise and with its clients. It forms part of the day-to-day way that things are done in the enterprise. In this sense, a service culture can be conceptualised as a "flow of values-driven activity", as opposed to being seen as a "thing".

Two seemingly opposing constructs of organisational culture emerge from the preceding discussion. The first is a more traditional deterministic management perspective of the concept of engendering a predetermined desired culture and a more contemporary view of culture as an emergent reality, emanating from the social interaction and discourse that takes place within the enterprise.

With the former in mind, Trompenaars and Prud'Homme (2004) suggest that institutions have consequently spent significant financial resources on consultants who were brought in to assist them to "roll out" a new desired culture.

This would be contradicted by the more contemporary complexity theory approach in dealing with the concept, which assumes that culture is an emergent phenomenon and the outcome of any initiatives to engender a services culture within an institution cannot be predicted with any degree of certainty.

McCormick (2008) states that "culture, for the most part, develops in an evolutionary unmanaged process".

Seel (2000) is a researcher who, even more pertinently, endorses the view of culture as an emergent property in stating that it "is the result of all the daily conversations and negotiations between the members of an organisation".

In researching organisational culture using a "meme" perspective, Weeks and Galunic (2003) conclude that "firms are best thought of as cultures, as social distributions of modes of thought and forms of externalisation".

The researchers use the term "meme" to refer "collectively to cultural modes of thought (ideas, beliefs, assumptions, values, interpretative schemas and know-how), to describe culture as a social phenomenon, patterns of symbolic communication and behaviour that are produced as members of the group enact the memes they have acquired as part of the culture".

Within this context, management can enact interventions that could give rise to favourable behavioural outcomes.

An important intervention in attempting to nurture a services culture could therefore be one of identifying change agents that could shape the narratives, negotiations and discussions that take place within institutional settings. Therefore, institutions become interpretation systems of participants who provide meaning to each other via their daily interactions, discussions and negotiations (Browining and Boudès, 2005).

In spite of the apparent complexity and difficulty involved, changing the way people think is still probably the most powerful means of ultimately changing behaviour, which, in terms of engendering a services culture, definitely has specific relevance (Pfeffer, 2005).

In laying the foundation for a services culture within an institutional setting, the accent should therefore be on creating contexts and patterns of discourse that give rise to the cultural attributes that are directed at building sound relationships with institutional clients.

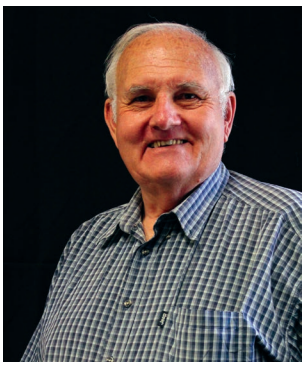
Conclusion

The apparent frustration in nurturing a services culture in South African institutions stems from a lack of understanding as to how such a culture becomes embedded in the social fabric of the institutions concerned.

It is therefore contended that the very foundation on which service delivery is based is flawed and that the traditional culture construct, which assumes that a desired culture can be realised through management processes, could well be the cause of the problem.

A description of organisational culture as a "system of shared actions, values and beliefs that develops within an organisation and guides the behaviour of its members" (Schermerhorn, Hunt and Osborn, 2008) may be more appropriate.

The role of executives and managers therefore needs to be one of becoming actively involved in influencing and shaping the discussions, negotiations and interactions that take place.



*The Graduate School of Technology Management (GSTM) mourns the loss of **Dr Richard Weeks**, who passed away on 16 March 2015. Dr Weeks established the Engineering Services Management domain at the GSTM and was extensively involved with students researching health-care services delivery from a National Health Insurance perspective.*

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An assessment of South Africa's research journals: impact factors, Eigenfactors and the structure of editorial boards

Androniki EM Pouris and Prof Anastassios Pouris

Journals are the main vehicles for scholarly communication within the academic community. As such, assessments of journals are of interest to a number of stakeholders, from scientists and librarians to research administrators, editors, policy analysts and policy makers, for a variety of reasons. A study was conducted that aims to identify the performance of South African journals that are indexed by Thomson Reuters' Journal Citations Reports.

Researchers would like to know where to publish in order to maximise the exposure of their research and what to read in order to keep abreast of developments in their fields. Librarians would like to have the most reputed journals available, and research administrators use journal assessments in their evaluations of academics for recruitment, promotion and funding purposes. Editors are interested to know the relative performance of their journal in comparison with competitor journals. Finally, policy makers have to monitor the quality of journals because they use published articles as indicators of the research system's success.

In South Africa, the assessment of scholarly and scientific journals is particularly important because higher education institutions receive financial support from government for their research activities. These institutions receive financial support according to the number of publications their staff members produce and publish in predetermined journals.

Two approaches, expert opinion and citation analysis, are used for the comparison and assessment of journals. In expert opinion assessments, experts such as well-known researchers and deans of faculties are asked to assess particular journals. Subsequently, the collected opinions are aggregated and a relative statement can be made. However, this approach has the same drawbacks as peer review. Will the opinions remain the same if the experts were different? How can an astronomer assess a plant science journal? Are there unbiased researchers in scientifically small countries?

The second approach is using citation analysis to rank journals. Citations are the formal acknowledgement of intellectual debt to previously published research. The impact factor of a journal is measured by the frequency with which the average article in that journal has been cited in a particular year. Despite the continuous debate related to the validity of Garfield's journal impact factor for the identification of the journal's standing, citation analysis has prevailed in the past (Vanclay, 2012; Bensman, 2012).

Scientific publishing in South Africa has experienced a revolution during the last ten years.

Scientific publishing in South Africa has experienced a revolution during the last ten years. In 2000, the South African government terminated its direct financial support to research journals and only the *South African Journal of Science* and *Water SA* continued to receive financial support. An investigation in 2005 showed that the termination of government involvement in the affairs of the journals generally had a beneficial effect on the impact factors of the journals.

During 2006, the Academy of Science of South Africa (ASSAf), at the request of the Department of Science and Technology (DST), produced a new strategic framework for South Africa's research journals. This strategic framework recommends, among others, the periodic peer review of the country's journals and a change in the publishing approach, i.e. a move into an open-access system. Finally, in 2008, Thomson Reuters substantially increased the coverage of South African journals.

The number of journals indexed in the Science Citation Index increased from 17 in 2002 to 29 in 2009 – an increase of 70%. The coverage of social sciences journals in the Social Sciences Index showed an even more substantial increase from four in 2002 to 16 in 2009 – a 400% increase.

Methodology

Assessment and comparison of journals according to their impact factors is a well-established approach in scientometrics, despite its limitations and shortcomings. The impact factor of a journal is defined as the quotient between the number of times an article published in a journal over the previous two years is cited in the year of observation and the number of articles this journal has published in these preceding two years. Today, the journal impact factor, as estimated by Thomson Reuters in the Journal Citation Reports, is one of the most important indicators in evaluative bibliometrics (Bornmann, Neuhaus and Daniel, 2011). It is used internationally by the scientific community, among other things, for journal assessments, research grants, academic subsidy purposes, and hiring and promotion decisions.

More recently, the Eigenfactor® approach has been developed and used for journal assessment (Bergstrom and West, 2008; Fersht, 2009). The Eigenfactor ranking system is also based on citations, but it accounts for differences in prestige among citing journals. Hence, citations from *Nature* or *Cell* are valued highly, as opposed to citations from third-tier journals with a narrower readership. Another difference is that while the impact factor of a journal has a one-year census period and uses the previous two years for the target window, the Eigenfactor metrics have a one-year census period and use the previous five years for the target window.

The composition of the editorial boards is an indicator of the internationalisation of the journal. It should be clarified that the editorial boards are both indicators of quality and inputs in the process of publishing a journal. For example, researchers are selective in terms of how they spend their time and would prefer to be associated with "top" journals. On the other hand, international researchers introduce standards and approaches in the peer review of the articles that may improve the relevant journals.

The performance of South African journals

Table 1 shows the impact factors, quartiles and scientific categories of the South African journals covered by the Journal Citation Reports during

→ *Table 1: Impact factors and quartiles of pre-existing South African journals in Thomson Reuters' Journal Citation Reports Science Citation Index in 2002, 2009 and 2010*

Journal	Impact factor 2002	Impact factor 2009	Quartile 2002	Quartile 2009	Quartile 2010	Category
African Entomology	0.455	0.420	3	4	4	Entomology
African Journal of Marine Science	0.754	1.520	3	2	3	Marine and Freshwater Biology
African Zoology	0.516	0.746	3	3	2	Zoology
Bothalia – African Biodiversity and Conservation[†]	0.358	0.242	2	4	3	Plant Science
Journal of the Southern African Institute of Mining and Metallurgy	0.052	0.216	4	4	4	Metallurgy and Metallurgical Engineering
				3	–	Mining and Mineral Processing
Journal of the South African Veterinary Association	0.366	0.224	3	4	3	Veterinary Science
Onderstepoort Journal of Veterinary Research	0.506	0.430	3	3	3	Veterinary Science
Ostrich	0.149	0.250	4	4	4	Ornithology
South African Journal of Animal Science	0.381	0.412	3	3	3	Agriculture, Dairy and Animal Science
South African Journal of Botany	0.394	1.080	2	3	4	Plant Science
South African Journal of Chemistry	0.265	0.429	4	4	4	Multidisciplinary Chemistry
South African Journal of Geology	0.659	1.013	2/3	2	4	Geology
South African Journal of Science	0.7	0.506	2	3	2	Multidisciplinary Science
South African Journal of Surgery	0.25	0.429	4	4	4	Surgery
South African Journal of Wildlife Research	0.224	0.562	4	4	4	Ecology
South African Medical Journal	1.019	1.325	2	2	2	General and Internal Medicine
Water SA	0.481	0.911	3	3	3	Water Resources

[†] Previous title was *Bothalia*

2002 for that year and for 2009 and 2010. The ranking to quartiles has been undertaken to consider the variation in citations among the various scientific disciplines.

Of the 17 South African journals in the Journal Citation Reports, four declined in terms of quartiles from 2002 to 2010. Only one journal – *African Journal of Marine Science* – improved its performance and moved from the third to the second quartile. *South African Journal of Geology* moved definitively into the second quartile in the list of the relevant disciplinary journals during 2009, while it was exactly in the middle of the second and third quartiles during 2002. During 2010, this journal moved into the fourth quartile. The journal's impact factor dropped from 1.013 during 2009 to 0.638 during 2010.

The examination of the impact factors indicates that 12 journals increased their impact factors. However, these increases were insufficient to move them into higher quartiles.

It seems that, as in the domain of journals, it has become more and more difficult to compete internationally. It is also interesting to note that *South African Journal of Science* – the country's flagship journal – exhibited a substantial drop in its impact factor and its position among multidisciplinary journals internationally during 2009. However, it recovered during 2010 and was part of the second quartile journals. It can be argued that this variability is the result of changes in the journal's management structure. Prior to 2009, the journal had a full-time editor. From 2009, it moved to a model with a part-time editor assisted by an editorial board.

Table 2 shows the impact factors, quartiles and scientific categories of South African journals that were recently added to the Journal Citation Reports. With the exception of *African Invertebrates,* which is positioned in the second quartile of the relevant journals with an impact factor of 1.216, all the other journals fall within the fourth quartile of their categories.

Inclusion in the international citation indices as an indicator of journal visibility is crucial. In South Africa, inclusion in the citation indices is particularly important, as publications in the indexed journals automatically qualify the country's universities for government subsidy. Universities in South Africa receive government subsidy according to a funding formula in which one of the components is the number of research publications. Universities currently receive more than R120 000 for each publication that their staff and students publish in qualifying journals.

The increase in the number of indexed South African journals during recent years undoubtedly increases the country's scientific visibility. A comparison of the journals' performance during 2002, 2009 and 2010 identified a relative decline in impact factor. During the most recent period, the majority of South African indexed journals belong to the fourth and third quartile in terms of impact factor. Only three of the scientific journals were in the second quartile. Similarly, all the social sciences journals were in the third and fourth quartiles. Journals in the tail of the Thomson Reuters

→ *Table 2: Impact factors and quartiles of South African journals newly added to Thomson Reuters' Journal Citation Reports Science Citation Index*

Journals	Impact factor 2009	Quartile 2009	Quartile 2010	Category
African Invertebrates	1.216	2	3	Zoology
African Journal of Herpetology	0.455	4	4	Zoology
African Journal of AIDS Research	0.569	4	4	Public, Environmental and Occupational Health
International Sportmed Journal	0.171	4	4	Sport Science
Journal of the South African Institution of Civil Engineering	0.125	4	4	Civil Engineering
Quaestiones Mathematicae	0.267	4	4	Mathematics
South African Journal of Enology and Viticulture	0.314	4	3	Food Science and Technology
Southern African Journal of HIV Medicine	0.457	4	4	Infectious Diseases, Virology
South African Journal of Industrial Engineering	0.093	4	4	Industrial Engineering
South African Journal of Obstetrics	0	–	4	Obstetrics and Gynaecology
South African Journal of Psychiatry	0.409	4	4	Psychiatry
Southern Forests	0.5	4	3	Forestry

ranking are at risk of being dropped from the citation indices. Furthermore, as researchers prefer to submit their articles to high-impact journals, the journals in the tail run the risk of not receiving an adequate number of quality articles, and hence will either reduce their quality standards or cease to exist.

The identification of the South African journals' Eigenfactors will provide a valuable benchmark of performance for future investigations, as there is currently no historical data of this indicator.

The identification of the structure of the editorial boards emphasises the above findings. The majority of South African journals are dominated by local researchers. As many as 20 journals do not have any foreign researchers or academics on their editorial boards. As international gatekeepers, they can transmit international standards and practices in local journals, and because they may increase the prestige of the journal with their presence, the relevant authorities should address the issue. It should be emphasised that international researchers on editorial boards alleviate the shortcomings of peer review in scientifically small countries like South Africa. It has been argued that, in scientifically small countries, a small number of researchers work in the same field. They know each other personally and are socially tied to each other and to the social community surrounding them. When these researchers have to render a verdict on a research proposal or research article, these ties impair them from being objective. While other approaches (such as monitoring the comments of peers and increasing the number of members on editorial boards) may be able to alleviate the challenges of bias, the incorporation of international researchers on editorial boards is probably among the most effective approaches.

The addition of new journals in the indices has implications for the future of science policy.

It is important for the prestige of the country, and of ASSAf, to take appropriate actions to improve the country's journals. The approach of coupling scientometric assessments with peer reviews can further provide evidence of the validity of the above findings.

The addition of new journals in the indices has implications for the future of science policy and warrants intensive relevant monitoring in countries like South Africa, which monitors their science performance using the Thomson Reuters indices. The addition of journals in the indices increased the coverage of the various countries' scientific articles, but created discontinuities in the time series data. Similarly, the differentiated coverage of the various disciplines (for example, social sciences versus engineering) can create changes in the countries' publication profiles. Science authorities should take action to create compatible time series and relevant country-scientific profiles.

Finally, it should be mentioned that the addition of South African journals in the citation indices has not adversely affected the country's scientific profile. Even though Thomson Reuters (2008) stated that "the importance of the [inclusion of the] regional journal is measured in terms of the specificity of its content rather than in its citation impact," this investigation shows that the newly added journals were of the same quality in terms of impact factor as the pre-existing ones.

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The nature and use of public open space in the City of Tshwane

Prof Karina Landman

Public space is important in cities. It is the common ground where people interact formally or informally to bind the community (Carr, Francis, Rivlin and Stone, 1992). It is also a place where one can meet strangers and engage with politics, commerce and sport. Therefore it is "a space for peaceful coexistence and impersonal encounters" (Walzer, 1989, cited in Madanipour, 1996).

Public open spaces also provide opportunities for recreation and relaxation (Gehl, 2011) and contribute to the greening of cities. This can enhance the quality of life of people and provide opportunities for more sustainable living. Given this, public spaces should be accessible to all, with physical and visual access from buildings and streets (Tibbalds, 2001). In essence, a public space can be summarised as "... space that allows all the people to have access to it and the activities within it, which is controlled by a public agency, and which is provided and managed by public interest" (Madanipour, 1996).

In theory, the City of Tshwane shares this view. The Integrated Development Plan (City of Tshwane Metropolitan Municipality, 2011) promotes the enhancement of the quality of people's lives, social cohesion and the need for open space. Along the same lines, the Tshwane Open Space Framework reiterates the importance of public spaces as key structuring elements in the city, and their ability to foster proper development. The Tshwane Vision Strategy 2055 (City of Tshwane Metropolitan Municipality, 2013) is premised on creating more sustainable communities and providing a better quality of life for residents. One of the ways to achieve this is through the development of a quality public realm with public space designed as civic art. However, many questions remain about public space in the city, with people often claiming that it is unsafe or dirty. In addition, the Tshwane Open Space Framework recognises challenges related to safety and maintenance in many parks. It therefore raises questions about the nature and use of open spaces in the city.

The Department of Town and Regional Planning at the University of Pretoria embarked on a multi-year project to investigate the spatial transformation of public space in South Africa, with a special focus on the City of Tshwane. The broader project is partly funded by the National Research Foundation (NRF) and aims to determine the changes in space over the last 15 years, the drivers of change, as well as the urban planning and design implications of these changes. The large project consists of many smaller projects.

One of these smaller projects involved multiple case studies in different types of public spaces in the city of Tshwane. Nine honours students of the Department of Town and Regional Planning studied 18 parks or squares in detail to determine the nature of the spaces or their physical characteristics through spatial analysis. They also described the use or function of these spaces through participant observation and interviews, and identified the perceptions of users towards spaces through interviews.

This article only focuses on nine of these spaces, including three inner city squares (Church Square, Lilian Ngoyi Square and Sammy Marks Square), three inner city parks (the park in front of the Union Building, Burgers Park and Venning Park) and three suburban parks (Magnolia Dell, Paul Cilliers Park and Waterkloof Glen Park).

The nine parks vary in size and nature. The park in front of the Union Building is very large in comparison to the other spaces. The squares are generally much smaller than the parks. Their physical characteristics also vary. Lilian Ngoyi Square and Sammy Marks Square are predominantly hard, open spaces with little vegetation, while Church Square offers a good balance. All six parks are predominantly soft, open spaces with large green areas, but some are formally designed, often incorporating a symmetrical design with classical structures (such as the park in front of the Union Building and Venning Park).

Most of the other parks have a more organic nature with flowing pathways or grass curvings between different types of vegetation, for example

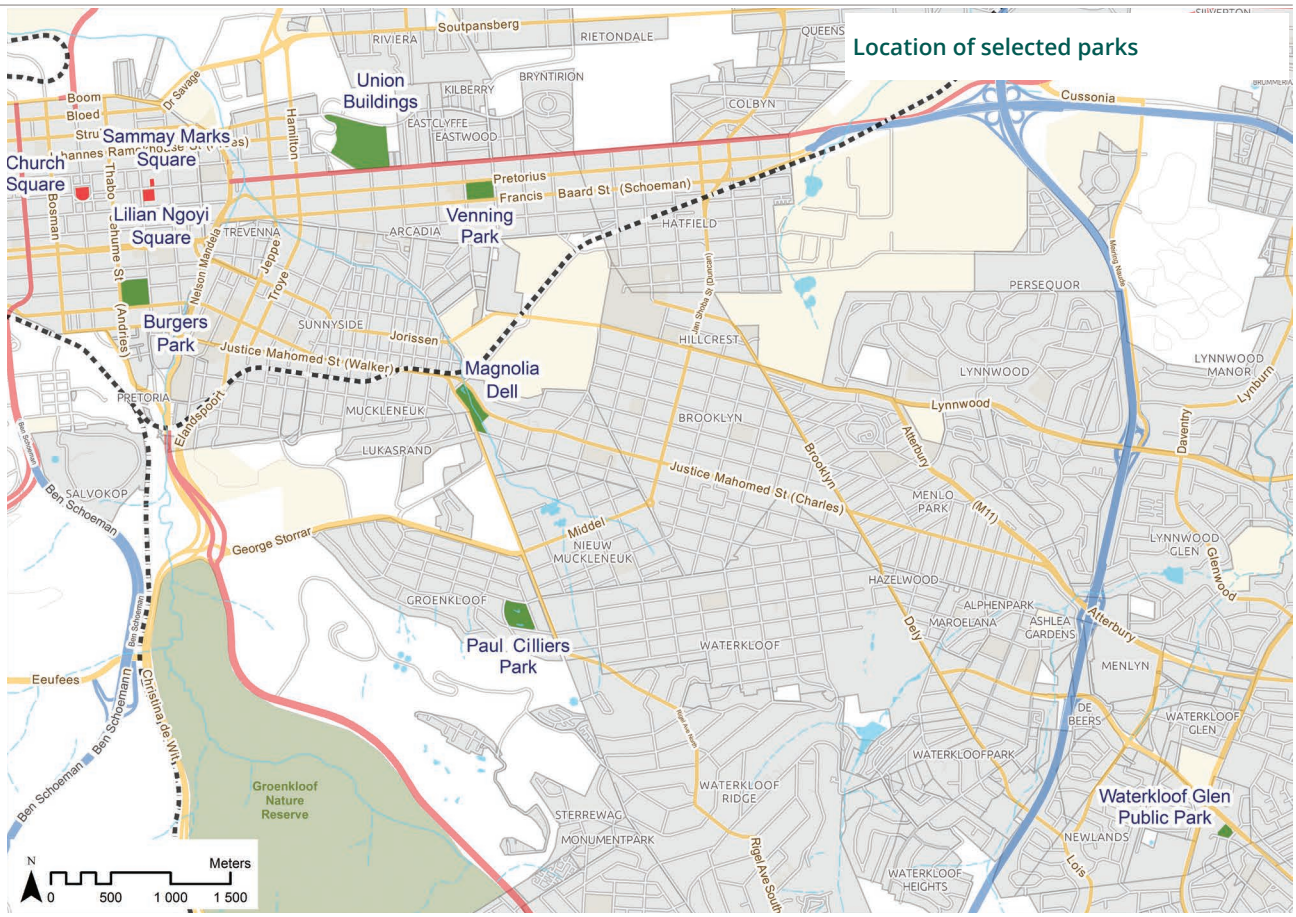

Figure 1: The location of the nine selected parks.

Magnolia Dell, Paul Cilliers Park and Waterkloof Glen Park. Church Square, the park in front of the Union Building and Venning Park include formal walkways.

The nature and primary function of the open spaces tend to influence the presence and type of building structures. The park in front of the Union Building offers the forecourt to the majestic Union Building on the hill. The formal terraces include many smaller structures and statues. Venning Park and Magnolia Dell include formal restaurants, kiosks and/or coffee shops, which cater for a variety of activities. Some of the parks offer restrooms. In the case of Magnolia Dell, these facilities were permanently locked. All the parks also included different types of water features, ranging from two dams in Paul Cilliers Park and a large pool in Venning Park, to small streams in Magnolia Dell and Waterkloof Glen Park. Different types of lighting and areas for seating were present in all six parks. However, the amount of seating varied. For example, in Sammy Marks Square, the seating was extremely limited.

The types of visitors and times of use vary. On weekdays, many of the inner city parks, for example the park in front of the Union Building, tend to be used by office and municipal workers who have lunch there. This also relates to the surrounding land uses and close proximity of office buildings. During the afternoons, most of the parks are frequented by children who use the playgrounds, for example Magnolia Dell and Venning Park. All the parks are utilised more extensively over weekends. Homeless people also occupy some of the more secluded areas in Venning Park, Burgers Park and Magnolia Dell. Informal traders are a common sight in the parks and on the peripheries of all the parks, with the exception of Paul Cilliers Park.

Photographers often use the parks to take photographs, especially at the park in front of the Union Building, Church Square and Burgers Park. Others enjoy taking photographs of the natural landscape and flowers, for example in Paul Cilliers Park.

Additional activities include just relaxing on the grass, having picnics or exercising. Yet, legitimate users tend to keep to certain areas, while homeless people and those consuming too much alcohol tend to hide in more secluded areas. In Paul Cilliers Park, other activities include test flying toys and helicopters, while Sunday events at Waterkloof Glen Park include church services. There are also informal markets and art exhibitions at Magnolia Dell on Sundays and tea/children's parties and stork teas at Paul Cilliers Park.

From the discussion, it is evident that most of the selected parks are still used, but that the use patterns are influenced by a variety of socio-spatial factors.

Interviews with the users confirmed that users are discouraged by crime, feelings of insecurity, people abusing alcohol, the

→ *The park in front of the Union Building with the Union Building in the background and the prominent statue of former President Nelson Mandela.*

→ *The small stream running through Magnolia Dell.*

presence of drug users and homeless people in some of the spaces, excessive noise and the nature of the built environment. People also complained about broken lights in parks, litter, too little shade, too few benches and a general lack of management. In spite of these concerns, people highlighted the fact that it was pleasant to visit most of these spaces due to opportunities for relaxation, connection to nature, watching people and social interaction. Interviewees also commented on their enjoyment of a peaceful and tranquil atmosphere.

→ *People relaxing in Burgers Park.*

Conclusion

The findings indicate that public spaces in the city offer places where people can interact socially and that, over time, these activities may contribute to binding the community. In addition, the findings also confirmed that Tshwane spaces are shared by strangers who are often not relatives or friends, and in this way, they can become spaces of peaceful co-existence. However, these noble ideals are threatened by a number of challenges, such as a lack of proper management, maintenance, adequate and accessible ablution facilities, as well as problems related to safety and security.

Fears are often related to the presence of illegal activities, such as alcohol abuse or drug dealing, and the presence of homeless people, as well as the nature of the built environment. Addressing the nature of the built environment may be easier, but the presence of homeless people raises a sensitive issue. Who should be able to use a public space in the City of Tshwane? Perhaps this warrants further consideration in the future, so that solutions may be developed to simultaneously make these spaces safer to use and to provide homeless people with proper places to stay.

Acknowledgements

The financial assistance of the NRF towards this research is hereby acknowledged. Opinions expressed and conclusions arrived at are those of the authors and cannot be attributed to the NRF. The map was produced by Darren Nel, Assistant Lecturer at the University of Pretoria, and the photographs were taken by Philippe Schockaert. Honours degree students Trisja Bezuidenhout, Lee-Ané Lombard, Ntswalo Mabuza, Nompumelelo Maditse, Celiwe Makena, Reabetswe Masombuka, Mapuleni Ndlovu, Leandra Raats and Lerina Schmidt also assisted with data collection.

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Aggregation and internalisation of electricity externalities in South Africa

Dr George Alex Thopil and Prof Anastassios Pouris

South Africa is currently undergoing extensive changes in the electricity generation sector because of the introduction of key renewable energy initiatives. The renewable energy initiative undertaken by the South African government has seen the participation of numerous independent power producers keen on exploiting the vast availability of natural resources. The generic incentive to employ renewable electricity generation schemes stems from the availability of resources and the lack of carbon emissions.

Despite the emphasis on renewable technologies, non-renewable technologies still play a significant part in the electricity generation mix, as highlighted in multiple impact assessment studies. South Africa is currently building and integrating renewable technologies on the national grid and, within the next two to three years, will require impact assessments of renewable generation mechanisms. To gauge the impacts of multiple generation mechanisms, it becomes essential to quantify the impacts of current electricity generation technologies. A study was conducted that aimed to quantify the external costs in the South African electricity industry and to investigate the relative impact of external costs when compared to local electricity prices. The final objective of the study is to scrutinise the policy implications of external costs and pricing for the electricity generation industry.

South Africa generates 95% of electricity from non-renewable electricity-generation mechanisms, which is primarily coal based. The abundance of coal reserves has historically made South Africa reliant on non-renewable electricity generation to support the increasing demand for electricity and extensive electrification programmes. South Africa produces 92.75% of its electricity from thirteen (ten base load and three peak load) coal power plants (Eskom, 2011). Some 5% of electricity is generated from the single nuclear power plant located at Koeberg on South Africa's West Coast. This allows a dependence on non-renewable electricity generation. The abundant availability of coal and its low cost is considered among the primary reasons for such a scenario. The dependence on coal-fired electricity also contributes to socio-environmental impacts that are categorised as externalities.

These externalities are classified as follows:

- Public impacts: The public health concerns caused during the process of electricity generation on a local and regional level
- Occupational impacts: The effects on the occupational wellbeing of staff involved in the process of mining for fuel and generating electricity
- Environmental impacts: Those impacts on the environment caused by generating electricity, which include the emission of greenhouse gases and using scarce resources

In economic terms, an externality is a cost or benefit resulting from an economic transaction that is borne or received by parties not directly involved in a transaction. Externalities have been defined in multiple forms and have been termed external effects, external diseconomies, third-party effects and spill-over effects Externalities were initially mentioned and classified as exceptions to the standard. As societies grew in material wealth, the incidence of external effects grew more into a standard than an exception, thereby requiring extended attention (Mishan, 1965).

The most important factor in this analysis is that all external cost (or externality) valuations were performed on data sets for 2008. This has been done to avoid distortions in estimates when comparing external costs to local electricity prices. Since local electricity prices in South Africa increased by between 25 and 33% between 2008 and 2013, comparing external costs with local prices would diminish the significance of external costs. Another reason to choose data sets for 2008 was to achieve uniformity in time frame for all evaluations that were performed.

The methodology used to evaluate externalities in this study was based on the Impact Pathway Approach (IPA) used in the Externalities of Energy (ExternE) study performed in the European Union.

The IPA methodology is mostly used during life cycle analysis (LCA) studies. However, this study is not an LCA of fuel cycles, but focuses solely on the generation stage of the fuel cycle. The IPA is used to analyse the generation stage of the fuel cycle, as well as the impacts associated with electricity generation. The IPA methodology is broken down into various stages, such as the identification of impacts, prioritisation of impacts, quantification of burdens, description of the receiving environment, quantification of impacts, economic valuation of impacts and assessment of uncertainty.

The total costs associated with the quantified impacts of electricity generation are summarised in Table 1.

It can be observed that the largest single contributor of external costs is the damages associated with greenhouse gas emissions. Damage associated with public health and water usage also constitute significant segments within total damages. Larger disparity between low, central and high estimates occurs within impacts that are significant contributors, which leads to the observation that the more significant the impact, the higher the associated uncertainty while quantifying the range of the damage.

While aggregate costs help determine impacts in terms of total damages caused, average costs are used to compare damages with respect to a common denominator, in this case the amount of non-renewable electricity generated. Average costs were estimated for quantified damages and are summarised in Table 2.

A classification of average costs differentiated by health impacts and environmental impacts is shown in Figure 1.

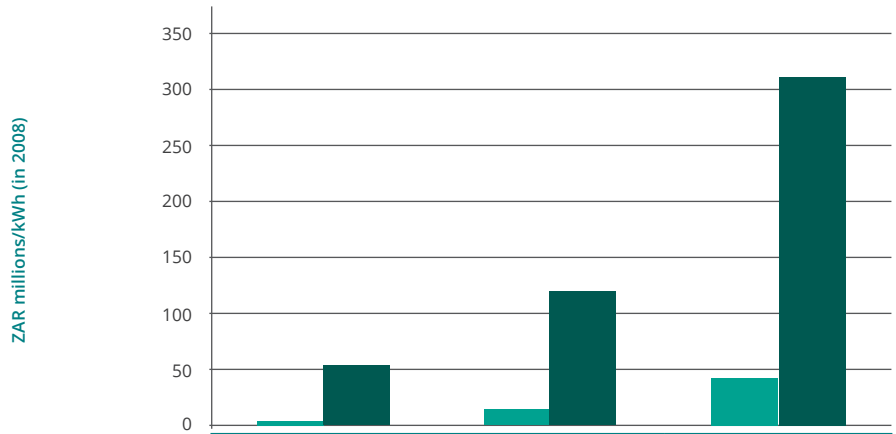
A quantification of external damages as a separate entity does not provide any added benefit to policy makers unless contextualised with electricity prices. The relative significance of external costs can be highlighted when compared with local electricity tariffs. The electricity tariffs for 2008 are categorised according to three sectors: average domestic tariff, average industrial tariff and average overall tariff, which are 44.56 c/kWh, 17.28 c/kWh and 19.59 c/kWh respectively (Eskom, 2009). The tariffs and percentage relativity are summarised in Table 3.

→ *Table 1: Aggregated external cost estimates (in million rands)*

Impact	Low	Central	High
Coal: Public health	847.10	2 681	8 770.40
Coal: Occupational health	(Not quantified)	77.66	(Not quantified)
Nuclear: Public and occupational health	8.44	13.71	18.98
Coal: Greenhouse gas environmental	11 258.6	25 444.5	66 651.8
Coal: Water usage environmental	435.40	626.55	819.75
Total	**12 549.54**	**28 843.42**	**76 260.93**

→ *Table 2: Average external cost estimates (in millions/kWh)*

Impact	Low	Central	High
Coal: Public health	3.90	12.37	40.50
Coal: Occupational health	(Not quantified)	0.36	(Not quantified)
Nuclear: Public and occupational health	0.75	1.21	1.68
Coal: Greenhouse gas environmental	51.96	117.44	307.64
Coal: Water usage environmental	2.00	2.89	3.78
Total	**58.61**	**134.27**	**353.6**



	Low	Central	High
Health (public + occupational)	4.65	13.94	42.18
Environmental	53.96	120.33	311.42

→ *Figure 1: Estimates of average health and environmental impacts*

→ *Table 3: Total average external costs relative to sectorial tariffs*

Sector	Average 2008 tariffs (c/kWh)	Total average external costs relative to tariffs		
		Low (5.86 c/kWh)	Central (13.43 c/kWh)	High (35.36 c/kWh)
Domestic	44.56	13%	30%	80%
Industrial	17.28	34%	78%	205%
Overall	19.59	30%	69%	181%

The above analysis leads to the conclusion that the inclusion of average external costs in the average 2008 electricity tariffs would cause an increase of 30 to 181%, with a central increase of 69%. The current externality analysis and internalisation into prices occurs at a time when significant changes are occurring in pricing mechanisms in the local electricity sector.

→ *Table 4: Average external costs using the ExternE methodology (in million Euros/kWh)*

Country	Human health (coal) central estimates	Greenhouse gas emissions (coal)	Human health (nuclear) central estimates
Belgium[1]	17.2	4–128	0.4
Germany[1]	11.9	3–111	0.18
Netherlands[1]	8.1	3–126	0.11
France[1]	48.4	4–151	0.44
Sweden[1]	0.7	3–102	0.41
South Africa[2]	2.25	9.43–55	0.22

Source: [1] European Commission, 1999. [2] South African prices are obtained from this study and adjusted to Euro values.

The South African electricity industry has seen a dramatic increase in prices over the past three years. The increases occurred because of the need to build additional generation capacity to meet increasing demand. These increases have been blanketed across all sectors and are based on a number of factors, such as type of sector, amount of usage and suburb in case of domestic pricing. South Africa's price of electricity, particularly within the industrial sector, has been one of the least expensive in the world.

With Eskom's priority centering on providing basic electricity to the masses, and electrification being the primary focus, generation capacity expansion was shelved. Incremental demand since the mid-1990s culminated in demand exceeding supply capabilities in 2008, with Eskom having to employ load shedding until demand stabilised. The formulation of the Integrated Resource Plan for Electricity (Department of Energy, 2011) was made with the intention of expanding generation capacity from the period 2010–2030, taking into account multiple possibilities to meet electricity demand. The process of expanding generation capacity meant increased revenues for Eskom, primarily as a result of increased tariffs.

The South African electricity industry has seen a dramatic increase in prices over the past three years.

The National Energy Regulator of South Africa (NERSA) regulates and determines electricity prices. NERSA's electricity pricing scheme is based on the multi-year pricing determination (MYPD). The MYPD was implemented according to Eskom's cost recovery requirements, so that the utility remains functioning and capable of sustaining itself economically (NERSA, 2010). The functioning and economic sustainability of Eskom is vital, especially when considering the significance of its role in the electricity sector in South Africa.

Local electricity sales from Eskom can be divided into the following categories: residential, commercial, industrial, mining, agricultural, traction and redistributors (municipalities). Industrial and mining (which are the two largest sectors) contribute 77% of sales, but generate only 67% of revenue, with the industrial sector having the largest disparity. The largest reverse disparity (where percentage of revenue from electricity

sales is greater than the percentage of electricity sales) occurs in the agricultural sector, which is a vital socio-economic sector in South Africa. The residential sector also shows a degree of reverse disparity. This leads to the question of whether the industrial sector, in spite of being the largest sector in terms of sales, is underpriced. One of the primary reasons for this is standing contractual agreements between Eskom and large industrial users such as mines. These contracts are equally beneficial for both entities, since the large industrial users contribute the largest section of revenue for the utility, while being able to keep their utility costs low.

Table 5 shows that South Africa's industrial electricity prices are among the cheapest in the world. These prices have been kept low in the past, and the adverse effects of this are now evident. Closer inspection of the prices shows that most countries have either avoided hiking electricity prices or marginally decreased or increased them during the period 2008–2009, which coincides with the economic downturn.

→ *Table 5: Electricity prices in US dollar/kWh adjusted for purchasing power parity [c]*

Country[a]	2007		2008		2009		2010	
	Domestic	Industrial	Domestic	Industrial	Domestic	Industrial	Domestic	Industrial
Belgium	14.51	9.62	18.53	9.83	16.05	11.39	16.85	10.87
Denmark	12.65	9.42	16.95	11.34	14.89	10.52	15.54	11.24
France	10.35	5.82	10.25	6.33	10.34	6.73	11.29	7.11
Finland	9.23	5.98	10.38	7.03	10.63	7.20	11.18	7.16
Greece	12.53	10.98	15.05	13.12	13.25	12.00	13.27	12.12
Ireland	17.64	12.89	18.85	14.93	18.10	12.95	18.83	12.99
Mexico	13.06	14.45	13.39	15.82	10.68	11.78	N/A	N/A
Netherlands	15.05	10.03	15.61	10.52	16.34	10.92	15.01	10.12
Norway	13.17	7.73	15.85	9.58	14.91	8.87	17.99	10.38
Spain	15.82	12.52	17.75	14.12	19.40	15.59	20.75	14.46
South Africa	9.95	3.81	9.97	3.86	11.25	4.56	12.81	5.41
South Korea[b]	11.49	8.44	14.09	9.93	9.67	7.43	N/A	N/A
Sweden	12.48	8.02	14.57	9.84	14.05	9.07	16.59	10.83
Switzerland	9.66	5.93	10.34	6.32	9.82	5.87	N/A	N/A
Taiwan	11.93	9.23	12.48	9.49	12.82	11.73	N/A	N/A
UK	17.38	12.72	19.61	13.45	17.78	12.91	17.89	12.42
USA[b]	10.06	6.17	10.34	6.44	11.05	6.87	N/A	N/A

a All prices were obtained from the Eurostat portal, except where mentioned (Eurostat, 2011).
b Prices obtained from "Energy prices and taxes" online database.
c Purchasing power parity (PPP) adjustments were performed using the online database of the Organisation for Economic Cooperation and Development (OECD).

Meanwhile, South Africa's electricity utility has been forced to increase prices significantly to recoup monetary resources to invest in the ever-increasing demand for electricity. These increases have taken place across the board for all sectors and are out of sync with the increases seen internationally.

In summary, the external costs that have been analysed and calculated in this study agree with international studies, which bring to light the necessity to tread with caution when considering long-term socio-environmental impacts. South African central external costs are roughly 70% of 2008 electricity prices. The major contributors of total central external costs (13.4 c/kWh) were public impacts from coal (1.23 c/kWh, 9.2%) and environmental impacts from coal (11.74 c/kWh, 87.4%).

South African external costs per kWh were found to be in the range of European countries that have used the ExternE methodology. It can be observed that significant variation occurs in the human health cost because of variable factors, such as the technology of the power plant, quality of coal used, site location, atmospheric conditions and population variables. However, greenhouse gas emission costs show less variance for the reason that local conditions have no effect on determining damage costs. Nuclear costs, on the other hand, show the least variance since technology and operating conditions are adhered to as per strict safety regulations, which are standardised globally. It is worth noting that South African valuations (while considering

This study analysed and calculated the external costs.

Renewable electricity generation mechanisms are a welcome addition to decrease the impact of fossil fuels.

uncertainties and variations) fall within the range of valuations performed in European countries using the ExternE methodology. The Southern African and African region, as well as other developing countries that do not have a mix of fuel sources being used for electricity generation, can use the methodology and results for benchmarking.

The internalisation of external costs by placing an environmental tax on general users is not feasible, considering the fact that prices are already being increased to raise capital to add new generation capacity. The presence of coal as a cheap, abundant resource is bound to keep South Africa reliant on coal in the near future. However, technologies such as retrofitted flue gas desulphurisation (FGD) and carbon capture storage must be considered for new building projects. The presence of renewable electricity generation mechanisms is a welcome addition to decrease the impact of fossil fuels. However, the variability and limited availability of solar and wind power, combined with the ageing national transmission grid, brings added risk when pursuing renewables without caution.

Policy prioritisation and pricing mechanisms need to be altered with a focus on curbing and decreasing the cause of the impacts of externalities. An integrated and coordinated approach between government and industry is required if such goals are to be achieved while maintaining the competitiveness of the local industry. The advent of the renewable energy programme has unlocked a range of opportunities and challenges in the South African electricity industry. The implementation of renewable energy mechanisms will provide a new range of technologies that will require external cost analysis, which can be compared with the existing technologies linked to the South African grid. The introduction of renewable technologies and cleaner non-renewable technologies could drive external costs (per kWh) down on one hand, but increased capacity and production could drive total externalities up on the other. These dynamics will have to be observed and will form the basis for future investigations.

Acknowledgements

Funding for this research was provided by the South African National Energy Development Institute (SANEDI). The authors would also like to thank Kristy Ross of Eskom for providing data for the research.

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→ *Incremental demand for electricity since the mid-1990s has culminated in the demand exceeding the supply capabilities.*

Prioritising control loop faults to maintain chemical industrial processing plants

Simon J Streicher, St Elmo Wilken and Carl Sandrock

The large number of control loops in a typical industrial chemical processing plant necessitates the prioritisation of control loop maintenance and optimisation, as inadequate instrumentation and control engineering staff cannot ensure that all control loops are operating satisfactorily at all times. A control loop is a process management system designed to maintain a process variable at a desired set point.

Although there are a number of methods for calculating individual control loop key performance indicators, the problem of ranking control loop fault importance has received limited attention.

A good ranking tool will rank underperforming control loops so that a control loop that affects the most important variables in the system will be ranked higher than one that may be underperforming, but affects less important variables. The indicated control loops should also be as close to the root cause of the fault as sensor placement allows, even if it is significantly amplified by another control loop.

In order to encourage the widespread adoption of the proposed solution, the tool should require minimal initial configuration and maintenance effort, and the ongoing operation should be automated and unsupervised. Many fault detection methods require some or all of the following: special excitations of the process, a benchmark of normal fault-free operation and a database of known faults. These specifications are generally undesirable or impractical in industry, as the necessary information is not readily available.

Many industrial operations already employ performance monitoring software to calculate individual controller performance indicators.

In the proposed method, predetermined importance scores are integrated with connectivity information and the economical attributes of streams in order to identify control loops with the greatest influence on profitability and stability. As an initial goal, a tool that will provide an automatic, daily list of the top 10 process tags most closely associated with the root causes of the most important faults will be developed.

The proposed method for ranking control loops from a maintenance perspective can be divided into three steps. The first is to model the plant as a digraph, where the nodes represent process elements and the edges represent physical or logical connections. Connectivity information may be obtained from knowledge-based methods, such as applying a reasoning engine on plant schematics. Alternatively, connectivity can be inferred by data-driven methods, such as transfer entropy. This is a non-parametric statistic measuring the amount of directed (time-asymmetric) transfer of information between two random processes.

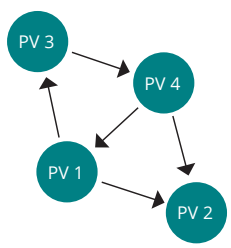
Indicating the correct connection of interaction is the most important function of the adjacency matrix. In mathematics, computer science and application areas such as sociology, an adjacency matrix is a means of representing which nodes of a graph are adjacent to which other vertices.

A convenient method for representing a binary-directed graph is an adjacency matrix as defined in Equation 1.

$$a_{ij} = \begin{cases} 1 & \text{If } v_j \text{ has an edge directed towards } v_i \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

Figure 1 presents an example of a directed graph with an accompanying adjacency matrix.

In the second step, edge weights indicating the degree to which the process elements affect each other under the influence of one or multiple faults are assigned to the digraph edges. Transfer entropy has been found to be a useful metric for this purpose, as it is an asymmetrical measure that is capable of capturing non-linear dependencies (Schreiber, 2000).



$$A = \begin{bmatrix} 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix}$$

Figure 1: An example of a directed graph with an associated adjacency matrix

Transfer entropy is very sensitive for time delays between time series data vectors. Therefore, it needs to be optimised over a reasonable range of potential time delays (Bauer, 2005). The edge weights can be represented in matrix form as a weight matrix similar to the adjacency matrix.

The third step is to determine the relative importance of the nodes in the directed graph. For this purpose, a modified form of the PageRank algorithm (Bryan and Leise, 2008), which is responsible for Google's initial success, is applied. This concept was first introduced by Farenzena and Trierweiler (2009), who dubbed the algorithm LoopRank in this context. This scheme of ranking nodes is generally referred to as Eigenvector centrality.

Each node's importance is calculated as the sum of the product of the importance of all nodes pointing to the node in question with their associated edge weights, as represented in Equation 2,

$$x_k = \sum_{j \in \boldsymbol{L}_k} e_{jk}\, x_j, \qquad (2)$$

where $\boldsymbol{L}_k$ is the set of nodes that have an incident edge to node x_k.

If this system is expressed in matrix form, the ranking problem reduces to the standard Eigenvector problem of Equation 3,

$$Mx = \lambda x, \qquad (3)$$

where M is the ranking matrix and $\lambda = 1$ for the ranking Eigenvector.

The gain matrix, which is the transpose of the column-normalised weight matrix, is shown in Equation 4.

$$m_{ij} = \left(\frac{w_{ij}}{\sum_j w_{ij}} \right)^T \qquad (4)$$

The transpose of the column-normalised weight matrix is used, as the interest is in finding the nodes with the most significant outgoing connections, as opposed to the standard form of the PageRank algorithm, which ranks the nodes based on the most significant incoming connections.

The Eigenvector centrality measure breaks down in the case of acyclic diagraphs, and non-unique rankings might occur if a graph is disconnected. A simple solution is to weight the adjacency matrix with a matrix-of-ones, as indicated in Equation 5, to create a fully connected structure, while still allowing the calculated weights to dominate the ranking results,

$$M_{connected} = (1-m)M + m\,J, \qquad (5)$$

where m is typically selected to be 0.15.

The proposed method to rank base layer control loop importance is demonstrated by the well-known Tennessee Eastman (TE) plant challenge problem. Ricker (1996) proposed a model that incorporates a decentralised control scheme, which is available in the Tennessee Eastman Challenge (TEMEX) archive. This model was used to generate results.

In this particular case, a full adjacency matrix was used to infer plant connectivity. No post-processing of the results was performed.

The edge weights were determined by calculating the transfer entropy between process tags using time series data sampled at intervals of 1.8 seconds. The global average of the local transfer entropies method for calculating transfer entropy was used.

Time delay optimisation was performed according to the form suggested by Shu and Zhao (2012).

Significance testing was performed through a non-parametric rank-order statistical test using surrogate data generated according to the Iterative Amplitude Adjusted Fourier Transform (IAAFT) method. The process was disturbed by a random fluctuation in the reactor cooling water inlet temperature. Figure 2 indicates the top ten flagged tags. The relative importance of the top ten process tags is shown in Figure 3.

A hierarchical directed graph (see Figure 4), is arguably the most useful form for presenting the results.

A number of nodes that provide a source of information without being influenced by any other nodes, together with the clusters of variables they influence, can be observed.

The results indicate the cooling water outlet temperature as the most originally influential process tag. The inlet temperature is unmeasured, making the outlet temperature measurement the sensor closest to the actual source of the disturbance. The reactor cooling water valve position was the only manipulated variable on

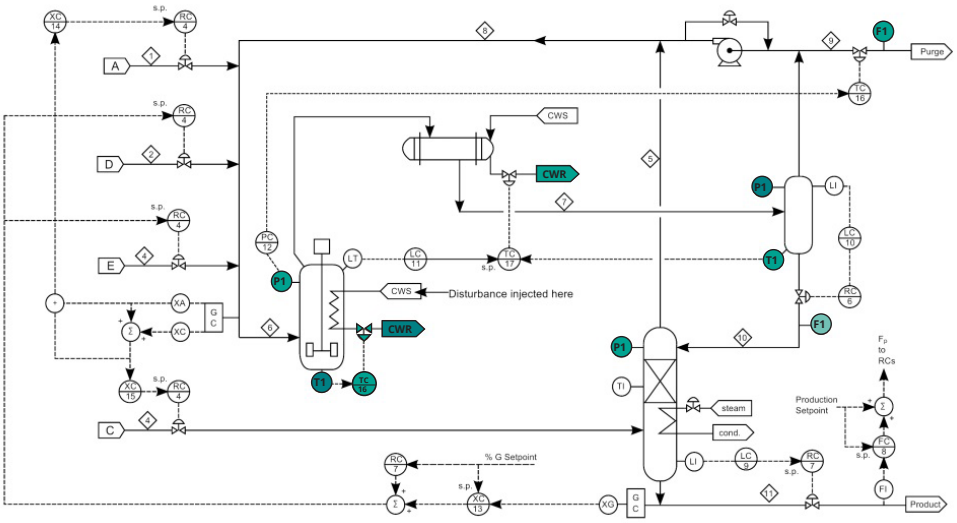


Figure 2: Process schematic with the top 10 indicated tags highlighted.

Rank	Tag description	Relative score
1	**Reactor CW outlet temperature**	
2	Reactor temperature	
3	Product separator pressure	
4	Product separator temperature	
5	Reactor pressure	
6	Reactor CW valve position	
7	Stripper pressure	
8	Separator pot liquid flow	
9	Purge rate	
10	Condenser CW outlet temperature	

Figure 3: Relative node rank for reactor cooling water inlet disturbance (CW = cooling water)

the list of the ten most influential process tags.

Thus, if a fault on the reactor temperature controller was detected, the control personnel would have been referred to the true source of the problem.

Incorporating controller performance indicators, as well as the economic value of streams as meta-data, associated with the nodes and solving the ranking problem together with a number of objective functions in a semi-supervised manner is expected to increase the relevancy of results.

Implementing a multiple time region analysis will allow the dynamic changes of information flow in the process to be analysed, which can be used to identify new faults and provide feedback on the effectiveness of maintenance.

Analysing deviations in information flow from long-term averages is expected to assist in dealing with the problem of certain process elements always having large importance scores due to the nature of normal plant operation.

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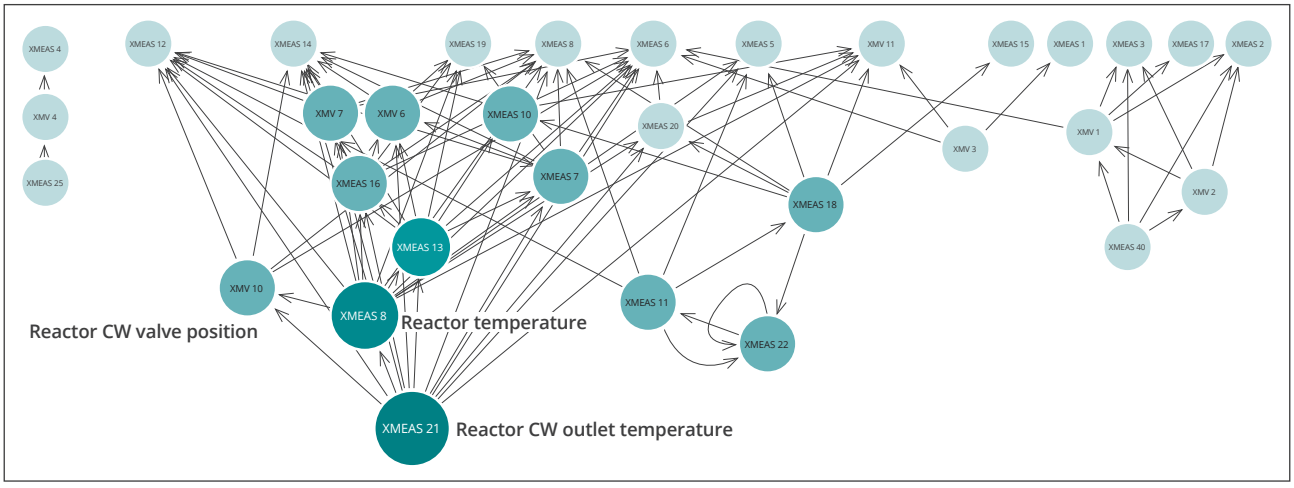


Figure 4: Hierarchical digraph presentation of results

Taking innovation to the next level

Prof David R Walwyn

Over the period 1994 to 2008, gross expenditure on research and development (GERD) more than doubled in real terms. This expenditure was driven mainly by rising government-funded research and development (R&D).

Since 2008, government funding has plateaued and GERD has declined. More worryingly, business expenditure on research and development (BERD) has dropped in real terms. This decrease was exacerbated by the closure of South Africa's pebble bed modular reactor (PBMR) project and would have been even more pronounced had it not been for Sasol, whose R&D expenditure now accounts for 12% of total BERD. BERD plays an important role in overcoming the low-growth trap from which South Africa must escape.

Although contested, the concept of the middle-income trap, which refers to the phenomenon where rapidly growing countries stagnate at middle-income levels, remains useful. It has been adopted as an analytical framework for many economies, including countries in Latin America, Africa and South-East Asia.

The basis for the middle-income trap is that rising wages in recently industrialised economies make traditional low-value exports uncompetitive in global markets. Moreover, these economies have limited capability in high technology or high value-added production, and cannot yet replace their declining share of commodity markets with speciality products and services. Such countries suffer from low investment, slow growth in secondary industries, limited industrial diversification and rising unemployment. In order to sustain stronger growth, these countries require specialisation in production, decentralised economic management, low inflation, stronger medium- and high-technology exports and reduced inequality.

Countries such as South Africa and (until recently) Brazil are frequently used as examples of the middle-income trap. This analysis is also reflected in the National Development Plan (National Planning Commission, 2011), which states:

> "South Africa displays features of a low-growth, middle-income trap, which is characterised by a lack of competition, large numbers of work seekers who cannot enter the labour market, low savings (hence a reliance on foreign capital inflows) and a poor skills profile. The net effect is a high level of unemployment, inequality and low levels of investment."

The plan recognises the central role of innovation in the country's development. It is also a means of escaping the middle-income predicament and refers to the importance of innovation in addressing the important developmental goals. It particularly recognises the need for R&D, internships for experiential learning and public policy focus on R&D.

In order to understand how innovation could be stimulated in the pursuit of inclusive growth, it is important to initially define the key success factors for innovation. Although there are many such interpretations, the following five main factors are highlighted:

- Innovation depends on a strong base of skilled human resources, which is equipped with the appropriate levels of education and experience (Cornell University, INSEAD and WIPO, 2014).
- Innovators' outputs are highly disproportionate, as a small group of innovators is responsible for most innovations. This probability profile is known as the Pareto distribution. It is also evident in a number of research outputs, including publications and patents (Walwyn and Sibisi, 2014).
- Innovation requires extensive risk sharing, most of which is absorbed by government funding. Although public research institutions have globally been the target of criticism and policy reform to minimise the state's role, these actions ignore the important role of such institutions in incentivising

investment, building networks and undertaking high-risk R&D. Repeated calls to downsize public institutions in order to "unleash the power of entrepreneurship and innovation of the private sector" have largely been overdone. It could lead to a weakened state that is unable to deliver on economic growth and foster radical innovation (Mazzucato, 2013).

- BERD is critical. The business sector understands markets, commercialisation and the positioning of a new product or service so that it can be an economic success. BERD supplies this pipeline and provides the knowledge that is subsequently embedded in innovative products (Cornell University et al., 2014).
- Innovation requires a vibrant and low-cost venture capital market, which is underwritten by high levels of capital availability in order to finance product development and economic growth. In developing countries, where foreign capital flows may be fickle and expensive, domestic savings (represented by a positive trade balance) are essential as a source of capital.

Although South Africa scores poorly in international surveys of human capital, especially at secondary and tertiary levels (Cornell University et al., 2014), the most recent R&D survey indicates two important aspects: rising numbers of full-time equivalent (FTE) researchers and more relaxed labour market conditions, as reflected by falling labour cost (expenditure per FTE).

Although levels of good education are not sufficiently widespread, the education system has pockets of excellence that are capable of delivering world-class scholars. For instance, South Africa ranks 18th on the global list of Nobel prize winners, ahead of all developing countries and many developed countries, including Finland, Ireland, Spain and New Zealand. However, retention of these top researchers is an ongoing challenge. Many of the country's top minds emigrate to Europe, the United Kingdom and the USA in order to pursue their careers.

A similar situation applies to the top innovators. Some prominent entrepreneurs, including Patrick Soon-Shiong, Mark Shuttleworth, Elon Musk, Pieter de Villiers, Roelof Botha, Percy Amoils, Chris Pinkham and Willem van Biljon now live in other countries. In terms of innovators or patent holders, South Africa, alongside many developing countries, records a net loss based on the listed authors of international patents. Furthermore, it has a low rate of patenting relative to other countries, a situation that has been deteriorating over the last ten years, as measured by the number of patents per FTE or R&D expenditure.

The problem of migration and "brain drain" in science and technology has been evident over a long period of time and several solutions have been attempted. The country's challenge is to retain such talent, especially in areas of high strategic focus, such as advanced manufacturing or information technology.

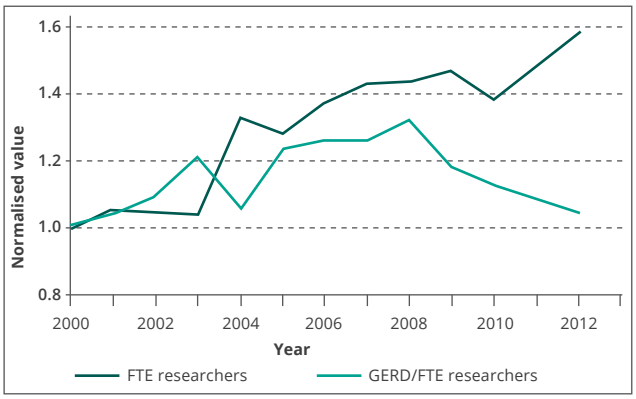


Figure 1: Number of FTE researchers and GERD/FTE (normalised to 2000)

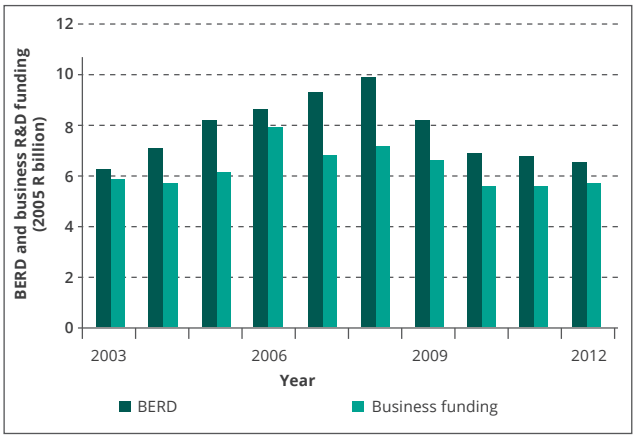
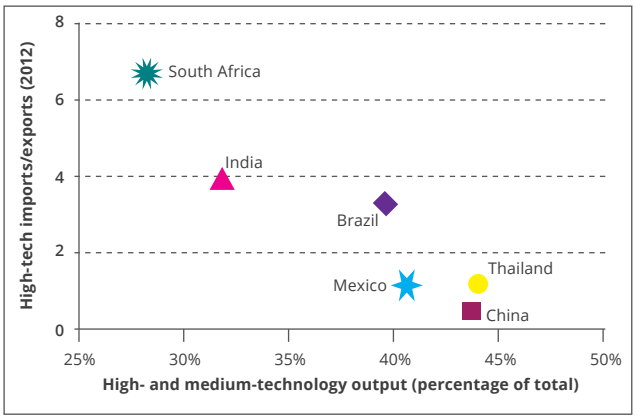


Figure 2: BERD and business R&D funding in constant 2005 R billion (2003 to 2012)



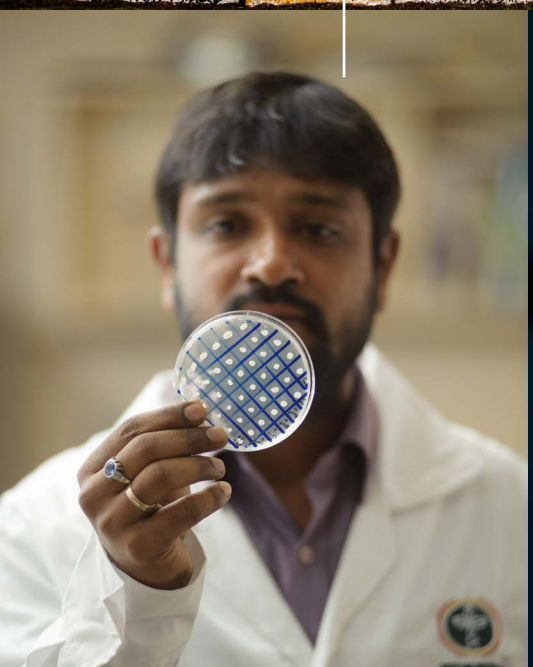
Source: Cornell University et al. (2014) and World Trade Organisation (2014).

Figure 3: High-technology manufacturing output supports exports in developing countries

Government or public funding of R&D has been growing in real terms since 1993, and has now reached 45% of the GERD, much of which is directed at early-stage, high-risk research.

At this stage, it is important to distinguish between funding and performance. Although BERD is defined as expenditure, it actually measures performance. In other words, the value for

→ *In most countries, government funds more research than it performs, and the business sector performs more research than it funds.*



BERD covers the amount of R&D performed by the business sector. Similarly, government funding of R&D covers funding and not performance. In most countries, government funds more research than it performs, and the business sector performs more research than it funds.

Much of the additional funding has been granted to universities, with government support of R&D in this sector rising by 450% in nominal terms or 250% in real terms.

Innovation holds the key to inclusive growth and recovering from the middle-income trap.

This funding focus, which indicates a growing role for universities as R&D performers within the national system of innovation, follows a pattern set earlier in many developed countries (OECD, 2011).

Business funding for R&D is perhaps the greatest concern in terms of innovation success factors. It is clear that both funding and performance of R&D in this sector has declined by 34% in real terms since its peak period from 2006 to 2008. The data for performance is complicated by the funding of the PBMR, in which government invested R8.8 billion from 1999 to 2010 (McKune, 2010).

The decline in business funding for R&D would be even more severe if one were to exclude Sasol, whose funding for R&D rose to R1.26 billion in 2012 (Sasol, 2013). A target or desirable value for BERD has been a much-debated subject over a long period of time, with values from 0.7 to 1.8% of gross domestic product (GDP) or at a company level from 4 to 25% of revenue, with little agreement on the value with the highest return or indeed the methodology by which this value can be calculated.

In earlier research, it has been suggested that South Africa's BERD should be about 0.9% of GDP (or about three times the present value of 0.34%) based on an analysis of the country's industry structure and benchmark values for each industry, as derived from an international comparison (Walwyn, 2008).

Local innovators are constrained by the limited availability and high cost of local venture capital funding for the commercialisation of R&D. South Africa needs to pursue other ways of addressing these constraints. The link between a positive trade balance, high levels of domestic savings and a reduced reliance on foreign capital flows has already been noted.

In summary, the most realistic path to this reduced reliance is to develop an export-based higher value-added industry, and thereby increase the level of high- and medium-technology exports.

Innovation holds the key to inclusive growth and recovering from the middle-income trap. Getting to the next level in terms of innovation intensity within the economy will require attention to several important factors.

In this article, it has been argued that these factors must include focus on value-added export-oriented manufacturing, the improvement of human capital, increased efforts to retain top innovators, and higher levels of BERD.

Together, these factors can realise new opportunities, including additive manufacturing, telecommunications, robotics, energy storage, artificial intelligence and digital genomes.

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Entrepreneurial tendencies of science, engineering and technology students

Prof Elma van der Lingen and Gerhard van Niekerk

Entrepreneurship has become increasingly important to enhance a country's economy. This has also resulted in various academic departments offering courses in entrepreneurship. Entrepreneurship is no longer only offered by business schools and faculties of economic and management sciences, but also by faculties of natural sciences and engineering.

Technology entrepreneurs, also known as techno-preneurs, are important in new-venture initiations, as they can identify business opportunities in the scientific and engineering space (Wickham, 1998). As the modern world is rapidly changing, it presents a magnitude of new technologies that can be developed into new ventures. These new developments not only demand technical skills from students in the natural sciences and engineering, but also business and entrepreneurial skills (Refaat, 2009).

A study conducted in the Graduate School of Technology Management (GSTM) aimed to determine the enterprising tendency of science, engineering and technology (SET) students and to compare these results with those of students in other disciplines and professions. The study further explored whether there is a relationship between the enterprising tendency of SET students and their first scientific degree, gender and ethnic group. The future aim of this study will be to structure technopreneurship courses in order to provide more effective training for SET students.

Measuring students' entrepreneurial tendencies

The General Enterprising Test (GET) was the primary measuring instrument used in this study. It is employed to determine the level of students' entrepreneurial tendencies. These tendencies (achievement, locus of control, need for autonomy, creative tendency and calculated risk-taking) are measured using questions from existing psychometric tests. In addition to the primary research questions, the researcher also captured profile information, such as gender, ethnic group and first scientific degree. The last variable is students' perception of the accuracy of the GET, as the students receive immediate feedback on the test results and have an opportunity to rate their perceived accuracy of the test.

Entrepreneur-ship traits need to be developed at an early age.

The survey population comprised honours students from the GSTM who were enrolled in the Engineering Management section of Technological Entrepreneurship. These students had already completed a first degree in engineering (BEng), science (BSc) or technology (BTech). The sample of this survey was self-selected. The researcher had no direct access to the test population and had to rely on the students' willingness to respond to an email invitation. The students were surveyed directly after completing the module, but before the final examination.

Identifying entrepreneurial tendencies

The study found that the respondents had an above-average enterprising tendency for the total GET score. The SET students' total GET score of 40 indicated that they would most likely be satisfied with being intrapreneurs who are part of a team within a corporation. The group had strengths in four of the five enterprising characteristics. A lower-than-average score was obtained for the subfield "need for autonomy". Because of the above-average enterprising characteristics in most of the subfields, the respondents were likely to be enterprising in some way, but most likely through intrapreneurship.

The comparison of GET results from studies conducted on other student groups and professions revealed the comparable overall enterprising tendency of SET students with existing entrepreneurs and business owners. Again, SET students scored lower in the subfield "need for autonomy" than the entrepreneurs and even some of the other student groups, such as MBA and undergraduate students, as well as professions, such as lecturers and teachers.

The SET students' first degree did not appear to influence their enterprising tendency, as no statistically significant results were obtained. However, further investigation into the enterprising characteristics or subfields revealed that the BEng students had a remarkably higher "need for autonomy" in comparison to the BSc and BTech student groups.

The results revealed that males have a higher enterprising tendency than females. At a statistical significance of $p < 0.001$, the results further indicated that males within the BTech group have a significantly higher need for autonomy than females in the same group. Other statistically significant results for this group indicated that males had a stronger tendency towards creativity, calculated risk-taking and internal locus of control than females. No statistically significant results were obtained for the BSc and BEng groups on the influence of gender on enterprising tendency.

The enterprising tendency study in relation to the ethnic groups showed that the white student group has a statistically ($p < 0.05$) higher propensity for the subfields "need for autonomy", "calculated risk-taking" and "internal locus of control" when compared to the black student group. Mueller and Thomas (2001) indicate that there is a link between willingness to take risks and internal locus of control. Preisendörfer, Bitz and Bezuidenhout (2012) also found that the black student groups tended to avoid risks due, for example, to fear of failure. On the other hand, the black student groups had a higher tendency for the subfield "need for achievement" in relation to the white student groups ($p < 0.1$). Interestingly, the black student groups had higher scores in the subfield "need for achievement" for all three SET groups (BEng, BSc and BTech).

In 2014, South Africa had an unemployment rate of 25.1%, which could escalate to the eighth-highest unemployment rate in the world by 2015. This rate includes a youth unemployment rate of 52.5% (World Employment Social Outlook, 2015). One of the 2013 *Global Entrepreneurship Monitor* (GEM) findings (Turton and Herrington, 2014) reveals that the number of young people in South Africa who believe that they have the entrepreneurial skills required to start a successful business is significantly lower than in most other developing countries. The South African population consists of approximately 80% black people and, in order to grow the economy and alleviate problems associated with unemployment and poverty, the country needs this ethnic group to become entrepreneurs and set up new ventures.

Entrepreneurial traits need to be developed at an early age, such as at primary and secondary school levels. However, a better understanding of tertiary students' entrepreneurial tendency could enable lecturers to develop courses that can stimulate entrepreneurial traits in order to enhance their potential for new venture creation.

Acknowledgement

Permission has been granted by the *South African Journal of Entrepreneurship and Small Business Management* to publish a summary of the paper submitted by Van der Lingen and Van Niekerk (2015).

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Corporate entrepreneurship education: individual and organisational entrepreneurial learning

Prof Leon Pretorius and Dr Bernd Platzek

Corporate entrepreneurship education is an important prerequisite for innovation and the management of sustainable growth in global business environments. Creating new opportunities in highly uncertain environments and pursuing entrepreneurial initiatives in new and established ventures requires an integrated view of corporate entrepreneurship and corporate entrepreneurship education.

Collaborative research conducted at the University of Pretoria's Graduate School of Technology Management (GSTM) explored a multilevel framework for holistic corporate entrepreneurship education.

Entrepreneurship is more relevant today than ever before. Entrepreneurial firms and agents drive innovation, renewal and development in today's globally competitive technology business environment. An organisation's viable interaction with the external environment involves identifying, selecting and pursuing opportunities in both established and new business ventures. Therefore, entrepreneurial firms require a corporate entrepreneurial mindset (systems perspective, on the firm level), entrepreneurial teams (interdisciplinary perspective on the team level), and corporate entrepreneurs (behavioural perspective on the individual level) with entrepreneurial motivation and skills that can be learned. According to Griffiths, Kickul, Bacq and Terjesen (2012) and Kuratko (2005), there is currently little progress in entrepreneurship theory and education for multilevel approaches. Consequently, there is a general lack of formal academic programmes in this field.

In today's environment, entrepreneurship drives innovation and management for sustainable growth. Corporate entrepreneurs and entrepreneurial teams create and implement new ideas proactively with a commitment to the enterprise's mission and life. They shape evolution and revolution as the organisation grows (Greiner, 1998) to reach the dynamic end state of a vital entrepreneurial learning organisation in permanent exchange with the external environment (Platzek, Pretorius and Winzker, 2014). To develop, manage and grow the business, individual and collective entrepreneurial learning from entrepreneurial practice is vital.

Most education theory does not explicitly refer to corporate entrepreneurship. It does, however, make sense to consider and review the existing theory for relevant content and pointers to educational aspects that require further investigation. Barbosa, Kickul and Smith (2008) focus on developing the analytic and intuitive skills that are necessary in the entrepreneurial process. Intuition and experiential thinking seem to be especially important in identifying opportunities. Reasoning and analytical thinking appear to be essential in the evaluation and implementation of opportunities.

In a proposed modular structure for corporate entrepreneurship education, Module 1 provides a basic understanding of corporate entrepreneurship. This module focuses on multilevel perspectives and forms of corporate entrepreneurship, entrepreneurial orientation and intensity, as well as opportunity analysis. It also deals with entrepreneurial processes, strategic renewal and organisational design elements for holistic corporate entrepreneurship, developing a business plan and business model innovation. These concepts form a knowledge base of the international business environment as a playing field for opportunities and risks, which are covered in Module 2.

Module 2 focuses on the character and elements of the business environment. An understanding of the general macro environment (political and legal, economic and social, and natural and technological) and the micro environment (industry, competitors and

markets) is a prerequisite for understanding the interaction between the organisation and its environment.

Content for Module 3 includes systems perspectives and thinking in entrepreneurial management, dealing with complexity, understanding formal, informal and political subsystems, as well as system planning and the recursive structures of organisations.

Module 4 looks at the building blocks of the vital entrepreneurial learning organisation. These building blocks include the design elements of holistic corporate entrepreneurship, entrepreneurial tasks and process models, the framework of the business environment, the qualitative systems model, and learning elements to develop and strengthen the vital entrepreneurial learning organisation.

Complementary to the organisational perspective in Module 4, Module 5 considers the personality of an ambidextrous corporate entrepreneur. The behavioural aspects, managerial and entrepreneurial mindset, entrepreneurial leadership, entrepreneurial preparedness, networking and relationship management, entrepreneurial activity, and management-level and general manager roles of the corporate entrepreneur are examined. According to Baghai and Quigley (2011), productive collaboration and collective action can only be achieved if the corporate entrepreneur's

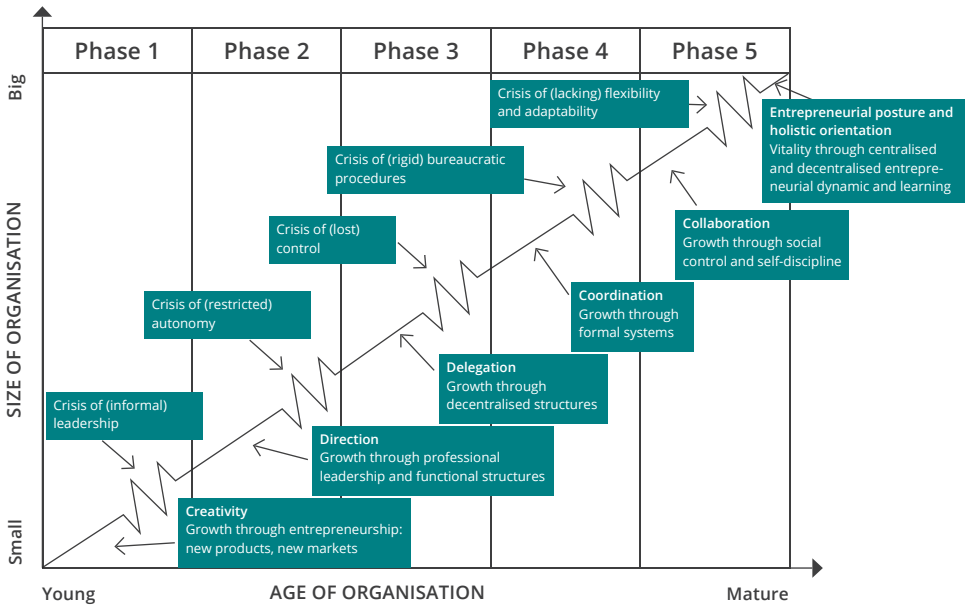


Figure 1: Evolution and revolution towards a dynamic end state of the entrepreneurial organisation as an open system along the lines of Greiner (1998).

individual actions are channelled.

To illuminate the general expectations of entrepreneurial managers, modules 6 to 12 reflect on the theory behind the roles of culture, change, innovation, team, communication and complexity managers. They also examine the characteristics and roles of effective managers.

Aside from studying entrepreneurship education theory, reflecting on practice significantly contributes to developing the intuitive and analytical skills required for entrepreneurial action. Modules 13 to 18 focus on individual study and experience (individual action), followed by presentations and discussions (group reflection). In Module 13, the corporate entrepreneur analyses the general macro environment of a country to identify and evaluate opportunities and risks. In Module 14, the additional intercultural issues regarding international markets are examined.

Module 15 focuses on analysing a specific micro environment. Corporate entrepreneurs should identify the industry characteristics, success factors, trends, competitors, opportunities and threats.

In Module 16, the internal study reflects on the specific role of the corporate entrepreneur for the whole organisation. The overall organisational architecture, which includes strategy, structure, culture, competences and resources, is considered. This helps entrepreneurs understand and evaluate the organisation-environment fit.

In Module 17, corporate entrepreneurs reflect, write a venture log and draw conclusions from past experience, such as the venture story and lessons learned, to use in future entrepreneurial activities. In Module 18, corporate entrepreneurs envision future entrepreneurial actions and write a business plan.

From the perspective of a vital entrepreneurial organisation, group reflection on entrepreneurial practice takes place in a workshop for shaping the entrepreneurial future (Module 19). Entrepreneurial teams reflect on opportunity recognition, idea generation and evaluation, synergy creation, and building parallel interests. Module 20 highlights the importance of reflecting on practices, such as performance in manager roles, progress in individual action plans and lessons learned, to strengthen entrepreneurial preparedness.

Entrepreneurial learning also takes place in managerial and

entrepreneurial fieldwork. Entrepreneurial actions create opportunities to learn about the entrepreneurship process and the implementation of opportunities. Individually, the corporate entrepreneur can reflect on entrepreneurial action in the manager roles. They should write a personal venture log and a personal competency log to turn theory into practice. Entrepreneurial learning could also take place through practice communities and it could be supported by coaching that responds to the needs and preferences of the corporate entrepreneur (Raelin, 2008). In addition to personal action plans, organisational action plans can be developed and discussed in collaborative learning. Group reflection in practice can be systematically channelled in organisational learning workshops (Module 19) or individual and team learning (Module 20).

When combining action and reflection in practice, reflection on practice, as well as classroom learning, it is possible to design a holistic corporate entrepreneurship education programme. Specific programmes based on this multilevel perspective, together with the entrepreneurial preparedness of the organisation and the individual corporate entrepreneur, can be designed.

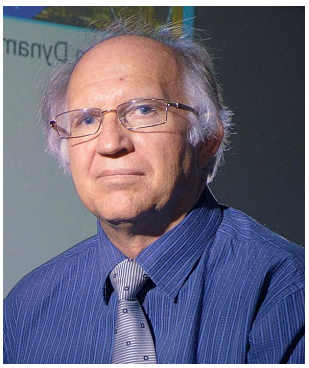
Following the implications from entrepreneurship education, a portfolio should be used in entrepreneurial learning. The theory component of such a portfolio should include seminars, workshops, exercises, presentations, simulations and literature studies. The practical component should comprise business planning, projects, experiments, reports, venture logs, competency logs, communities of practice, meetings, networks, discussions, coaching, competency feedback, learning from success and failure in entrepreneurial action, learning from crises and fortunate coincidence, interviews and document studies.

Conclusion

This study explored holistic corporate entrepreneurship by introducing the concept of holistic corporate entrepreneurship education. It is argued that the current dynamic business environment makes a multilevel approach with individual, team and organisational learning valuable. Theoretical and conceptual exploration led to the development of a generic entrepreneurial learning programme with 12 theorectical and eight practical modules. Two of the practical modules represent extensive entrepreneurial learning in practice. Further conceptual and business research can help specify the modules and training in more detail for application in any specific organisational context.

Acknowledgements

This research was supported by the German Federal Ministry of Education and Research (Competition Advancement through Education: Open Universities).



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Have a light bulb idea? Entrepreneurship is the process of starting a business, typically a startup company that offers an innovative product, process or service.

The adoption of 3D printing

Prof Leon Pretorius and Prof Harm-Jan Steenhuis

Three-dimensional (3D) printing is not a new technology. It has been present since the 1980s, but has only been available to the consumer market in the last two years. Many people have viewed 3D printing, which is a form of additive manufacturing, as a disruptive innovation, because it allows consumers to manufacture their own products.

According to Sung-Won (2013), it is one of the seven most disruptive innovations. Hyman (2011) states that the technology is among the top 10 technologies that will transform the next decade. It is viewed as disruptive for both manufacturing and service. However, some researchers question how disruptive it is really going to be.

Exploratory collaborative research conducted at the Graduate School of Technology Management (GSTM) aimed to investigate 3D printing and its emerging markets.

Methods for 3D printing

The most common form of additive manufacturing is 3D printing (Budmen and Rotolo, 2013), although the two terms are sometimes used interchangeably. Additive manufacturing is the process of building an object in many layers (Barnatt, 2013). Due to the combination of design software and the absence of a mould, it has made manufacturing a possibility for virtually anyone. One of the reasons why 3D printing is often considered a disruptive technology is that it does not require specific manufacturing skills.

There are a few different technologies for 3D printing. The first is fused deposition modelling (FDM), which is a material extrusion process similar to the process used in a two-dimensional (2D) inkjet printer. A company called Stratasys invented FDM and has trademarked the term. Subsequently, other companies refer to this technology as plastic jet printing (PJP), fused filament modelling (FFM), fused filament fabrication (FFF), the fused deposition method or simply thermoplastic extrusion (Barnatt, 2013). During this process, the printing material, usually a special type of plastic that comes on a spool, is heated and led through the printer head. It is then spread on the printing surface. Additional layers are put on top of each other, similar to repeatedly printing the same letter on the same spot, so that the ink layer becomes thicker and a noticeable three-dimensional structure appears. Aside from plastic, this technique can also be used for metals, wood, concrete and even chocolate. One disadvantage of FDM technology is that it can be slow. There is also a possibility that products may warp or shrink as a result of the cooling process.

The second method of 3D printing is stereolithography. According to Barnatt (2013), stereolithography is a 3D printing technology that builds objects in layers using a stereolithographic apparatus (SLA). This process involves a container with a chemical liquid. A printing bed is positioned near the top of the container so that there is only a thin layer of liquid on top of it. This layer is then exposed to light, typically a laser, which solidifies it. The printing bed is then lowered a tiny fraction so that another thin layer of the liquid is formed on the newly created layer, and the process is repeated.

An alternative to stereolithography is digital light processing (DLP). With this technology, a DLP projector is used to selectively solidify a polymer liquid (Barnatt, 2013). Another alternative is two-photon polymerisation (2PP). This nanophotonic 3D printing method is very similar to stereolithography, but works on a very small scale. An advantage of SLA is that the products are smoother. However, it is a more expensive technology and requires the handling of chemicals.

The third method of 3D printing is selective laser sintering (SLS). SLS is a powder bed fusion 3D printing technology that uses a laser to selectively sinter together the granules of successive layers of powder (Barnatt, 2013). There are some similarities to the SLA process, but instead of a liquid, it uses powder. Thus, a thin layer of powder lies on top of a building surface. A laser traces the shape of the object and the build platform is slightly lowered. A new thin layer of powder is placed on top of it and the process is repeated.

A fourth, quite different method of 3D printing is laminated object manufacture (LOM). LOM builds objects in layers by sticking together laser-cut sheets of paper, plastic or metal foil. In the LOM process, a feed mechanism advances a thin sheet of material onto the build platform. The material either has an adhesive backing or at this stage has adhesive applied. A roller (sometimes heated) then passes over the sheet to press it into place. A laser finally cuts the outline of an object layer into the sheet, and the build platform lowers just a little. The process is then repeated until all object layers have been created (Barnatt, 2013).

Consumer market

The 3D consumer printing industry is in an early, turbulent stage of development. In some ways, it resembles the early home computer market where several technology-oriented hobbyists were building their own home computers. Some of these entrepreneurs were successful in launching their computers, such as the ZX Spectrum and the Commodore 64, into the market, and numerous clones were also produced. It is believed that more than 250 companies make personal 3D printers and a few generated revenues of $1 million or more within a year of the printer's launch (Wohlers Associates, 2013).

One of the most recent introductions comes from Dremel. In September 2014, this tool-manufacturing company introduced its 3D Idea Builder (Mearian, 2014). Some companies, such as MakerBot, even have their own retail stores. Several other companies have aligned themselves with chains, such as Home Depot or Staples, where their printers are now being sold.

The main characteristics of 3D consumer printers include the build volume, print speed and print accuracy. As can be seen from Table 1, the printers are still expensive and typically only allow the manufacture of small products.

Industrial market

In contrast to the 3D consumer printer segment, fewer companies operate in the industrial market. In 2013, 34 manufacturers around the world produced and sold industrial 3D printing systems (Wohlers Associates, 2013). In 2013, while growing by 26.4% compared to 2012, an estimated 9 832 machines were sold for an average price of US$90 370, while the cumulative figure is 66 702 units (Wohlers Associates, 2013). The market share of industrial manufacturers is mainly held by two companies: the US-based 3D Systems and Stratasys (see Figure 1).

Market development

Figure 2 illustrates the number of units sold in the industrial market during the last two decades. The annual sales of industrial systems in 2015 are expected to exceed 15 000 units, which means that the industry will exceed $21 billion by 2020 (Wohlers Associates, 2013). However, it is not clear how this relates to consumer 3D printers, because many personal 3D printers are non-traditional and difficult to track.

This study used bibliometrics to investigate worldwide 3D printing trends. The Google Scholar database was analysed and cumulative trends of the 3D printing growth associated with the industrial and consumer market is shown in Figure 3. First, it can be seen that the cumulative trends of 3D printing technology seem to be different for industrial and consumer applications. For example, it should be evident from Figure 3 that the cumulative industrial trend is 2 800 units, as opposed to 600 units for the consumer trend in 2010. This seems to disprove the implication that fewer companies operate in the industrial market compared to the consumer market. However, one should remember that this bibliometrical analysis could imply that more activities have been associated with industrial markets and the development of 3D printing technology than for the ensuing consumer markets during the same times of development.

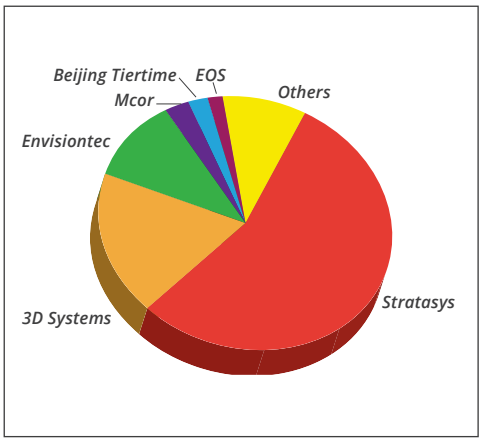
Conclusion

The evidence produced in this study seems to indicate four different methods for 3D printing technology. This research evidence supported the technical and advanced nature of 3D printing as an additive manufacturing approach.

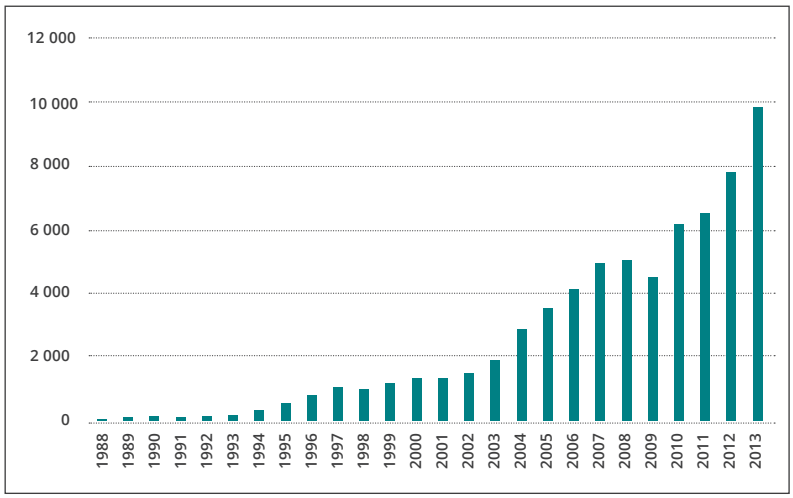
→ *Table 1: Consumer 3D printer comparison*

Company	Build volume (inches)	Print speed (mm/sec)	Print accuracy (mm)	Price
Afinia H-Series	5.5 x 5.5 x 5.3	3–30	0.4–0.15	US$1 299
Cube	5.5 x 5.5 x 5.5	15	0.2	US$1 299
Felix	10 x 8 x 9	10–200	0.05	US$1 749
LulzBot TAZ4	11.7 x 10.8 x 9.8	200	0.075	US$2 194
MakerBot Replicator 2X	11.2 x 6 x 6.1	80–100	0.34–0.1	US$2 799
MakerBot Replicator Fifth Generation	9.9 x 7.8 x 5.9	Not available	0.1	US$2 899
Orion Delta	5 x 5 x 9	40–300	0.05	US$1 499
Printrbot Simple	3.9 x 3.9 x 3.9	70	0.1	US$349
Printrbot Simple Metal	6 x 6 x 6	Not available	0.1	US$599
Ultimaker 2	9 x 8.85 x 8	30–300	0.02	US$2 499
Ultimaker Original+	8.25 x 8.25 x 8	30–300	0.02	US$1 599

Source: www.makershed.com/pages/three-dimensional-printer-comparison



→ *Figure 1: The market share of industrial manufacturers (based on Wohlers Associates, 2013)*

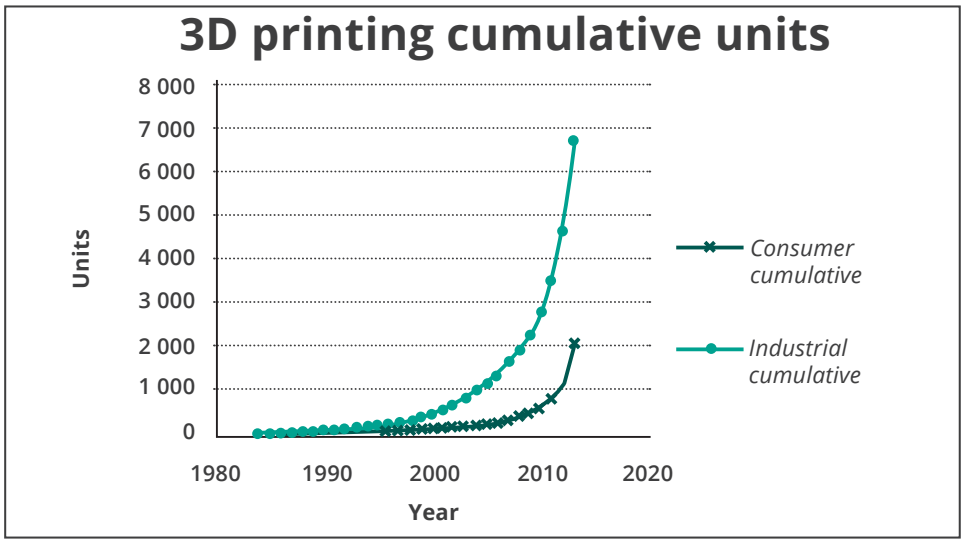


→ *Figure 2: Industrial machines sold per year (Wohlers Associates, 2013)*

Some initial company evidence gathered pointed to a difference in the industrial and consumer approaches to 3D printing.

A distinct difference was identified in the market growth patterns for industrial and consumer applications. In terms of 3D printing technology between 2002 and 2013, the ratio of consumer to industrial penetration has increased from 0.12 in 2002 to 0.42 in 2013. This points to a possible increased focus on consumer applications for 3D printing.

Further research may include the identification and analysis of additional case studies in the industrial and consumer application of 3D printing technology. Additional databases, such as patent sources, may be used to enhance the current 3D printing technology. System dynamics modelling may also be used to enhance the 3D printing market development analysis and possible technology trend forecasting.



→ *Figure 3: Bibliometric results for 3D printing technology diffusion in cumulative units.*

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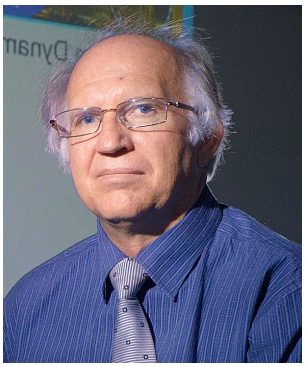

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Using biodegradable material as electrical and electronic components

Prof Joe E Amadi-Echendu, Johnson Okorhi and Aderemi Helen Olubunmi

Access to information and communication technology (ICT) has been identified as an indicator of a country's economic and social development. The rapid growth of the ICT sector has therefore led to an improvement in the capacity of electrical and electronic equipment, which has also led to a decrease in product lifetime, so that the volume of waste generated increases annually by 10% .

Many countries lack the infrastructure and resources needed to manage electrical and electronic waste (e-waste) in an environmentally sound manner. Some West African countries, including Benin, Côte d'Ivoire, Ghana, Liberia and Nigeria, now face huge challenges in e-waste management.

Public nuisance and health challenges that arise from e-waste disposal are of serious concern to humanity and the environment. The exposure to e-waste hazards in and around dismantling sites causes manifold health and safety risks for scavengers, recyclers and neighbouring populations (Basel Convention, 2011a). Hazardous substances are released during various e-waste dismantling and disposal operations, particularly during the burning of cables to liberate copper and plastic to reduce waste volumes.

The production and use of electrical and electronic equipment needs to be revisited through the application of technology frontiers that are environmentally compactable and safe.

Chemical composition of e-waste

Many components of electrical and electronic equipment contain aluminium, copper, lead, cadmium, zinc, mercury, ferrous metals, glassware/ceramics and thermoplastics. A personal computer (PC) comprises 26% silica or glass and 23% plastic. Metals constitute 51% of PCs. These materials normally biodegrade very slowly, with full degradation occurring in 500 to 1 000 years (Irimia-Vladu, Głowacki, Voss, Bauer and Sariciftci, 2012). Generally, e-waste, as a composite material, is not necessarily hazardous, but harmless natural substances become hazardous during the manufacturing process. For example, chromium becomes hexavalent chromium, which is a human carcinogen when inhaled.

Rising e-waste trends in Nigeria

The media has paid considerable attention to the trade of used electrical and electronic equipment in Nigeria. An estimated 500 containers of used electronics and computers are imported into Lagos ports daily. In 2010, containers of imported used electrical and electronic equipment in categories 2 to 4 were analysed between May and July by monitoring shipment manifests and providing shipping information for about 176 containers. The results revealed that almost 60% of the containers came from the United Kingdom (UK), with Felixtowe as the dominant exporting port. More than 75% of all containers came from Europe, approximately 15% from Asia, 5% from African ports (mainly Morocco) and 5% from North America.

In the light of this rising trend, the National Environmental Standards and Regulation Enforcement Agency (NESREA) recently ordered a vessel carrying e-waste at the Tin Can Island Port in Lagos to send its consignment back to the UK. NESREA cited the provisions of the Nigerian Harmful Wastes Act of 1988, which was promulgated after the Koko waste saga in 1988. Local Nigerian officials discovered the illegal toxic waste stored at the port of Koko. Some first-world countries saw Nigeria as an illegal dumping ground for e-waste and the waste was more toxic than many had realised. Many workers started to need hospitalisation, with problems ranging from chemical burns and nausea, to paralysis. By 2011, NESREA had intercepted five ships carrying e-waste destined for Nigeria.

Chromium becomes hexavalent chromium, which is a human carcinogen when inhaled.

Technology frontiers

In order to mitigate the e-waste crisis, more biodegradable components should be included in electrical and electronic equipment. According to Irimia-Vladu et al. (2012), many organic materials, including natural compounds, have been shown to be biodegradable, safe and non-toxic. Biodegradation is a natural form of recycling. Until recently, legislations, policy, guidelines and standards merely governed the transboundary movement of hazardous waste and its disposal, together with take-back and extended producer responsibility (EPR) programmes for end-of-life electrical and electronic equipment, (Basel Convention, 2011b; NESREA, 2011). The application of organic field effect transistor (OFET) technology, organic thin-film transistors (OTFTs), organic light-emitting diodes (OLEDs) and organic photovoltaics (OPVs) in the manufacture of electronic devices promotes the sustainable management of e-waste.

Research conducted to find replacements for some of the inorganic components of electronic devices suggests that biodegradable components would be a better choice. Experimental tests have shown that the integration of active organic materials into e-devices has allowed the implementation of low-cost, lightweight and flexible sensing devices. Such usage is currently proposed in the field of environmental monitoring, military defence and preventative medical care.

→ *The search for biodegradable material for use in computer components is a vital step towards curbing e-waste and the impact it has on human health.*

Advancements in biomaterial processing and organic electronic device fabrication have allowed the potential integration of biomolecules as active components in all the materials employed in the realisation of an organic transistor, including the bulk substrate, dielectric interface, active semiconducting layers and electrodes.

Irimia-Vladu et al. (2012) suggest that silicon-based electronics can also be fabricated onto silk, and the silk can be used as a bioresorbable carrier. Silk has also been used as a substrate for passive radio frequency identification (RFID) circuits that can be integrated directly onto food, such as apples and eggs as sensors of food quality. In addition, silk can be fully biodegradable and can be engineered to degrade under chosen conditions, allowing selected drug storage and delivery.

> The best technologies yield multiple gains in the field of environmental protection, working conditions and employment creation.

These findings also identify gelatine, which is commonly used for oral medication capsules, as a good substance for electronic components. Electronics built on hard gelatine could easily be ingested for specific biomedical applications that target a short examination time. The placement of organic field effect transistor components directly onto hard gelatine capsules has also been demonstrated.

In addition to electronic conduction, several biological materials are ionic conductors (Irimia-Vladu et al., 2012). The earliest organic electronic "device", a resistive switching element, was based on melanin, a biological polymeric material that is responsible for brown-black skin pigmentations in animals and humans (Angione, Pilolli, Cotrone, Magliulo, Mallardi, Palazzo, Sabbatini, Fine, Dodabalapur, Cioffi and Torsi, 2011). It has been employed in several sandwich diode devices. Proton-conducting materials, which have been extensively researched for fuel cell applications, have recently been documented as a huge prospect in biocompatible electronics. Many conducting polymers are uniquely suited as bioelectronic interfaces, because they can conduct both ionic and electronic currents. Both modes of conduction have potential application in biodegradable electronic products and biomedical

devices. These common conducting polymers have been shown to be non-toxic and remarkably biocompatible (Schwabegger, Mujeeb, Irimia-Vladu, Baumgartner, Kanbur, Ahmed, Stadler, Bauerb, Sariciftci and Sitter, 2011; Angione et al., 2011).

Policy direction towards biodegradable electronic components

In the field of waste management, EPR is a strategy designed to promote the integration of environmental costs associated with electrical and electronic equipment throughout their life cycles into the market price of the products. It is an environmental protection strategy to decrease the environmental impact of electrical and electronic equipment by making the manufacturer of the product responsible for its entire life cycle.

Manufacturers are now advised to enclose information leaflets on e-waste management and the best strategy to involve business and industry in corporate citizenship responsibility programmes, including the EPR and buy-back mechanism (Basel Convention, 2011a). In Nigeria, the introduction of a buy-back mechanism has yet to gain ground because of government uncertainty in enforcing a sound EPR programme in terms of e-waste (NESREA, 2011). However, Nokia, the mobile phone manufacturer, has embarked on the collection of used mobile phones in 83 buy-back centres in Nigeria (Osibanjo, 2009).

Samsung, another electrical and electronic equipment firm, produced 45 million OLED displays in 2011, and aims to produce up to 600 million units by 2015 (Irimia-Vladu et al., 2012).

Conclusion

The best technologies yield multiple gains in the field of environmental protection, working conditions and employment creation, as well as in general economic terms.

Such practices encourage the formal application of the five Rs of e-waste: reduce, repair, reuse, recycle and recover (NESREA, 2011), minimise occupational and environmental hazards, and promote economic benefits.

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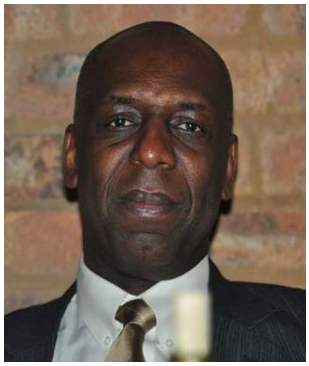

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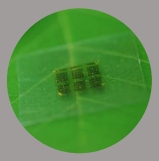


More bio-degradable components should be included in electrical and electronic equipment.

Establishing a relevant national tender price index for the local building industry

Dr Hoffie Cruywagen

Construction cost indices are used on a daily basis in the construction industry for a number of reasons. As there is currently only one tender price index in use in South Africa, a study was conducted to examine the use and compilation of cost indices, which may lead to the construction of a new tender price index for the South African building industry.

According to Steyn, Smit, Du Toit and Strasheim (2007), "an index is a ratio that measures relative change", while Flemming and Tysoe (1991) state that "index numbers of cost and prices provide a convenient means of expressing changes over time in the cost or prices of a group of related products in a single measure".

Steyn et al. (2007) are of the opinion that one must distinguish between simple and composite indices on the one hand and unweighted and weighted indices on the other. A simple index is used to represent the price change of a single commodity, while a composite index represents the price changes of more than one commodity. Furthermore, when an unweighted composite price index is calculated, the price changes of all commodities are regarded as equal, while different weights are allocated to the different commodities in a weighted composite index. All the important indices used in the construction industry are weighted composite indices.

Flemming and Tysoe (1991) state that three main types of indices are used in the construction industry. Input price indices reflect local market prices and can be used to reimburse the contractor in respect of cost increases in labour and material. Examples of such indices are the Construction Price Adjustment Provision indices published by Statistics South Africa on a quarterly basis (Statistics South Africa, 2009). Output/tender price indices attempt to measure the total cost of the construction of a completed structure in each location, taking local conditions into account, changes in productivity, as well as contractors' profit margins. For these types of indices, both a Laspeyres index, such as Stellenbosch University's Bureau of Economic Research (BER) building cost index, and a Paasche index, such as the Building Cost Information Services (BCIS) index in the United Kingdom (UK), may be used. According to Statistics Norway (2007), seller's price indices not only include all the costs of the completed construction project, but also the cost of land, finance costs, professional fees, value-added tax (VAT), as well as the seller's profit. This type of index is not used much in the local building industry.

Indices in South Africa

During the early 1960s, a quantity surveyor responsible for research and development at the erstwhile Department of Public Works (DPW) in Pretoria, developed an index for the DPW. In the mid-1960s, the BER was looking for a deflator for building prices and, according to Kilian (1980), obtained permission from the DPW to take over this index.

Marx (2005) reports that the index is based on a 100 m^2, single-storey building to which a concrete slab was later added. From this building, 22 cost components were selected and expressed as quantities. Segalla (1991) states that these components were used because they represent items from the original building and are weighted in proportion to the role that they play in the total cost.

Another index is the little-known Contract Price Index for buildings (Van der Walt, 1992). All that is known about this price index is that it was compiled by a quantity surveyor at a private practice in Pretoria. The research that was done during the compilation of the index was adapted and presented at the University of Pretoria as part of a PhD thesis in 1992, but the study was conducted in the early 1970s. The details of the index were made available to the erstwhile Central Statistical Services (CSS), today known as Statistics South Africa.

When constructing a new index, the following factors should be considered:

- **Choice of formula:** It was decided to steer the investigation in the direction of a fixed-weight, short-list method with priced

bills of quantities as the basis (Laspeyres index). The main reason for not using the Paasche index is because of the unavailability of a so-called "price book" as in the UK. Such a price book is compiled every year and can be used to reprice bills of quantities with base rates, as the BCIS has done.

- **Preliminaries:** This forms an important part of any contract and can fluctuate between contracts, as well as varying economic climates. Segalla (1991) notes that the BER allows a 5% fixed amount per project. For this study, however, it was decided to spread the preliminaries as priced for each project as a percentage across all rates.

- **Provisional sums:** Neither the BER nor the BCIS makes provision for provisional amounts in their indices. Because provisional amounts, as currently priced in contracts in South Africa, can be as high as 40 to 50% of the contract amount, it is considered an important item that should form part of a new index. The decision was therefore made to include the amounts for the main items such as electrical and mechanical installations on own merit in the index.

- **Influence of region and site:** Although it is anticipated that there will be differences in the prices of labour and material across different regions, only the rates will be influenced by it. This problem could be overcome if a sufficient number of priced bills of quantities could be sourced and average rates could be used. It is considered that on-site conditions will be reflected in the rates for poor soil conditions and that it would not influence any other rates.

It was therefore decided to base the calculation of a new index on a fixed-weight, shortlist of indicator items, mostly because priced bills of quantities are freely available, as it is still one of the preferred procurement methods in South Africa. In order to establish weights for such an index, it was decided to use the analysis of different buildings to compose an "average" representative building. This is an accepted method of calculating construction price indices, as indicated by Van der Walt (1992), who states that a set of standard weights may be used for all buildings. In Finland, the weights of the building cost index are based on the estimated share of four different types of projects (flats, houses, offices and warehouses) (Statistics Finland, 2001).

In order to obtain a representative sample, another purposive sample was done by requesting priced bills of quantities from quantity surveying firms. Firms across South Africa were requested to submit priced bills of quantities for new or so-called "green fields" projects that were executed between 2005 and 2012. Ultimately, the bills of quantities of 231 projects received from 37 firms were used. The projects covered the period January 2006 to June 2012 and represent 26 quarters in total.

The first step after the collection of bills of quantities was to analyse these projects. This was done on a Microsoft Office Excel spreadsheet by going through the bills of quantities of each project and listing the tariff of the various items that were selected as indicator items to make up the weighting. In the first phase of the analysis, more items were extracted from the bills of quantities than those that had been listed. The reason for this was that, in some instances, the exact item as listed might not have been available, but a close substitute was.
An example of such items could be found in the formwork trade, where items with different propping heights and/or different slab thicknesses were similar to the original indicator item. The amount for preliminaries for each project was added proportionally to the rate of that project. After this process had been concluded for all projects, the analysis was refined by compiling another spreadsheet. This time, the spreadsheet contained only the rates for one indicator item (those that matched or were closest to the original).

The Construction Price Adjustment Provision Index is one of the indices used in the construction industry.

When analysing the captured unit rates, substantial differences were found in the unit rates for the same item during the same period. This concurred with literature on the subject. Various options were considered on how to deal with such outliers in the rates. One option was to set upper and lower limits to the mean rate, for example, 30% above and 20% below. If any rates exceeded these upper or lower limits, they were substituted with either the maximum or minimum rate. Another option was to calculate the standard deviation from the mean rate and use this as a limit. However, this method allowed too many rates to fall outside this limit and would therefore change the distribution dramatically (Van der Walt, 1992).

Both options were tested in this study, but after consultation with the Department of Statistics at the University of Pretoria,

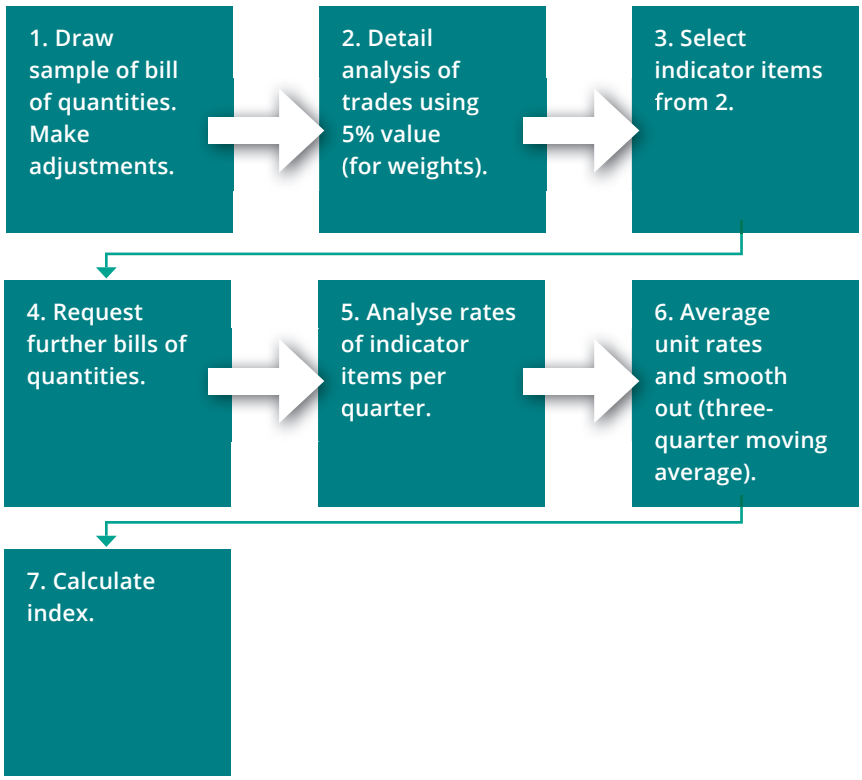


Figure 1: A flow chart of index calculation

it was decided to use a more simplistic method where only the highest and lowest rates was discarded from a series of similar rates and the mean of the remaining rates were calculated. These figures would then be used as the base rate for that quarter. The advantage of using this method is that the majority of the rates in a series are considered, which is beneficial where a low number of rates have been received in a particular series.

After doing the above calculations, the averaged rates were transferred to another spreadsheet. Even though the rates had been averaged, it became apparent that there was still a large amount of fluctuation among the rates that appeared from one quarter to another. After further discussions with the Department of Statistics, it was decided to smooth the rates further by calculating a three-quarter moving average for each rate for the period under investigation.

A tender price index indicates the movement of a basket of rates over a period of time.

Figure 1 gives an overview of the various stages of the index leading up to the calculation of the actual index.

After completing the abovementioned steps, the complete index for the period under investigation could be calculated. This was achieved by calculating the total of the base year quantities at current rates, divided by the total of base year quantities at base year rates, multiplied by 100 (for each quarter in the study period).

A tender price index is an indication of the movement of a basket of rates over a period of time. The new index under scrutiny should be examined in this context.

For research purposes, the index can be referred to as the "UP 2006" index. The index showed an upward curve as of 2006 (UP 2006 = 100) to about the end of 2008 where it peaked at 158.99. This represents an increase in prices of almost 60% over the two-year period (or eight quarters), or an average of approximately 7.5% per quarter.

This period in the history of the South African building industry overlapped with a worldwide boom in construction activity, especially in the light of the 2010 Soccer World Cup that was upcoming at that time. The general movement of this peak in the UP 2006 index therefore seemed to be justified.

The boom in construction activities was followed by a sharp decline. This could be attributed to the conclusion of the 2010 Soccer World Cup projects, as well as the worldwide economic recession, which also had an impact on the South African economy.

The UP 2006 index showed a similar movement with the trend declining from 158.99 in the fourth quarter of 2008 to a low of 106.24 in the second quarter of 2010. This represented a decline of 33.18% over a six-quarter period with an average of approximately 5.5% per quarter. After this, the UP 2006 index showed a relatively consistent movement over the next two years until the end of the research period.

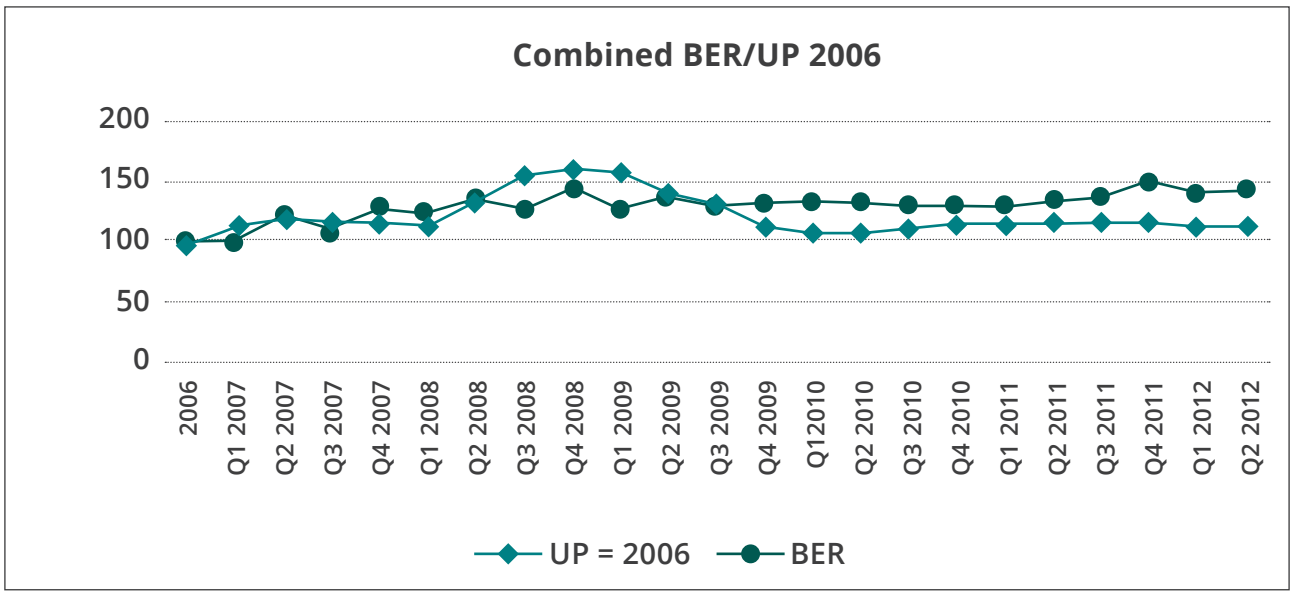


Figure 2: Combined BER/UP 2006 indices.

This movement seemed to be consistent with what emerged from the projects that were investigated during this period, namely that tendered rates did not show a significant increase during this two-year period.

It was a logical step to do a comparison between the BER's building cost index and the UP 2006 index. In order to compare the two indices over the same period, it was necessary to extract information for the BER index from information published by Medium-term Forecasting Associates for the same time period (2008 to 2012), and then to extrapolate the data.

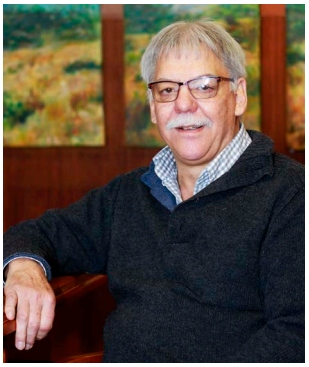
As can be seen from Figure 2, there is a reasonable degree of correlation between the two data sets. The biggest difference is shown from the second half of 2009, where the UP 2006 trend is sharply downwards, whereas the BER trend is more gradual.

Conclusion

It may be concluded from the data presented that it is possible to construct a new tender price index based on accepted norms and standards regarding index theory, and on studies conducted on other similar indices.

In order to test the validity of the UP 2006 index, it is suggested that comparisons be made with the movement of the economy in general over a longer period. It will also be beneficial if a larger sample of priced bills of quantities could be obtained to make it statistically more stable.

To achieve this, a new method of collecting these projects will have to be considered. This could be done in collaboration with the Association of South African Quantity Surveyors (ASAQS). The UP 2006 index can also be made available to the quantity surveying community on a quarterly basis for comments and testing in a commercial environment.



Dr Hoffie Cruywagen *is a senior lecturer in the University of Pretoria's Department of Construction Economics. His research interests include building cost indices, professional practice, standard systems of measuring and research methodology. He is the author and co-author of a number of peer-reviewed academic papers and has presented papers at national and international conferences.*

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Environmental Engineering

The Environmental Engineering Group in the Department of Chemical Engineering has been active since January 1993. Originally, the group focused on knowledge-based capacity-building in the South African industrial sector through the honours programme in Environmental Engineering or Applied Science and Technology. For the past five years, the focus of the programme has shifted towards research into pollution reduction processes and energy technology development.

The group has produced five PhD and 28 MSc or MEng graduates working on a wide range of environmental engineering and environmental sciences topics since 2010. Research topics address the growing needs of South Africa's economic development in line with the national priorities articulated in the National Development Plan (NDP), Vision 2030. The NDP Vision 2030, which is the successor to the National Strategic Agenda of Government (2010–2014), aims to set South Africa on the path towards an economy based on renewable and cleaner energy sources and processes that are environmentally cleaner and more sustainable.

Among the notable projects conducted by the Environmental Engineering Group include recent research on copper oxide-doped ultraviolet (UV)-titanium dioxide semiconductor photocatalysis, in which the power of the UV energy from natural light sources is unleashed in the degradation of organic impurities in water; reducing atmospheric emissions from clamp kilns in the South African clay brick industry; and determining the impact of engineered nanomaterials on the environment.

The team members of the Environmental Engineering Group are Prof Evans Chirwa, Prof Ndeke Musee, Dr Gerrit Kornelius and Dr Deon Brink, who are supported by two postdoctoral fellows: Dr Neetu Bansal and Dr Zainab Birungi.

Clean water and waste-to-energy innovations

Prof Evans Chirwa

Recent research on copper oxide-doped ultraviolet (UV) titanium dioxide semiconductor photocatalysis conducted in the Department of Chemical Engineering has revealed how the power of the UV energy from natural light sources can be unleashed in the degradation of organic impurities in water.

This technology makes it possible to improve the recycling of supernatant water from sludge ponds that receive backwash water and sludge from sedimentation basins at water treatment plants (Chirwa and Bamuza-Pemu, 2010). Lately, water wastage at treatment plants has escalated in the summer months due to excessive algal blooms (green soup). The revenue loss can be as high as R1 million per month for a sizeable plant that treats over 150 million litres of water from eutrophic water bodies per day.

It is customary to avoid recirculating water from sludge ponds to avoid the accumulation of the organic compounds that are produced by blue-green algae. These algae cause problems such as foul odour and taste due to the presence of the algal metabolites geosmin and 2-methyl-isoborneol. Disinfection by-products (DBPs), such as trihalomethanes and haloactetic acids, are also formed during disinfection with chlorine gas. DBPs are known to increase the rates of mutagenesis and cancer in populations that consume water with high organic content for prolonged periods.

The research group has also embarked on multidisciplinary research on the bioremediation of heavy metals, as well as nutrient removal and recovery from water and sludge. An example of this research is the project on bacterial reduction and the removal of the toxic forms of the metals chromium (VI) and uranium (VI) to the less toxic and less mobile trivalent (Cr(III)) and tetravalent (U(IV)) forms, respectively, that are easily removed by filtration and electrokinetic processes (Molokwane and Chirwa, 2009; Mtimunye and Chirwa, 2014).

In the most recent projects, the reduction and immobilisation of the metals were accomplished in microbial permeable reactive barriers (MPRBs) and in fixed-film bioreactor systems. Gram-positive species of bacteria from sludge samples completely reduced Cr(VI) to Cr(III) in a water sample with a Cr(VI) concentration of up to 400 mg/l. Gram-negative bacteria from uranium tailings dump soil achieved up to 92% removal of uranium (VI) in batches with a concentration of up to 200 mg/l. In both cases, the microorganisms

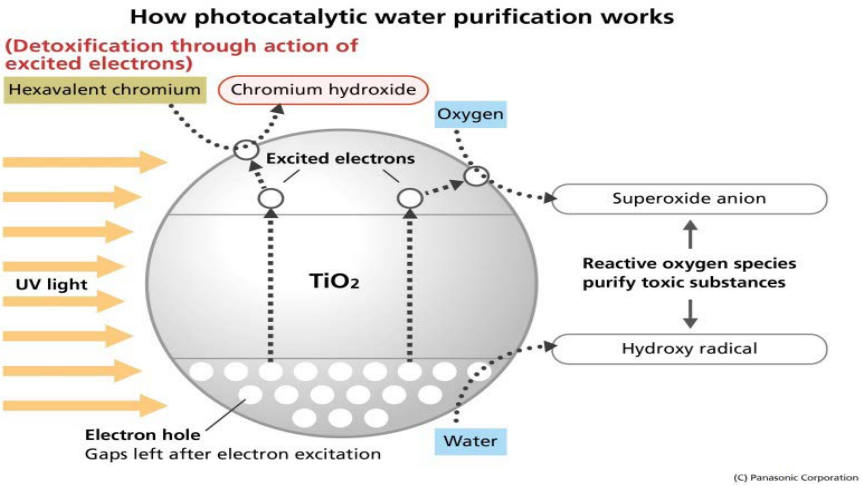
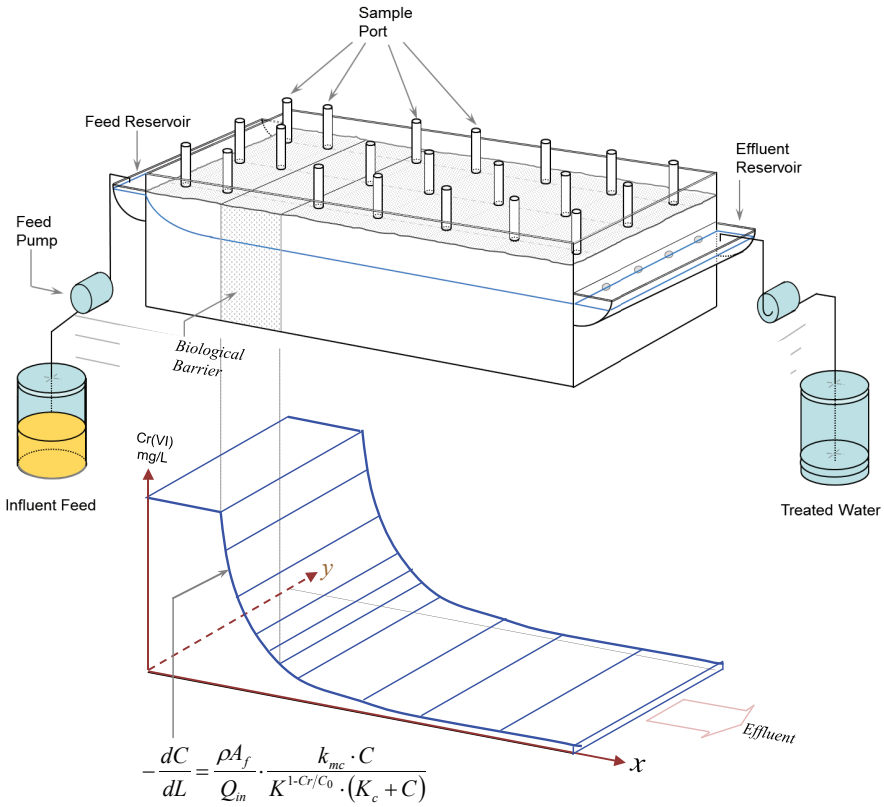


Figure 1: How photocatalysis works during the detoxification of water.

→ *Algal growth studies for utilisation in wastewater treatment.*



→ *Figure 2: A bench-scale reactor system for Cr(VI) reduction and immobilisation in a simulated groundwater flow biological barrier system.*

that achieved the removal of the toxic metallic species were isolated from local wastewater and mine dump soil environments. Using this method, it has been demonstrated that the detoxification of wastewater streams containing high levels of metals can be achieved at a low cost by using environmentally compatible biological processes.

The Environmental Engineering Research Group in the Department of Chemical Engineering has developed concept proposals on the creation of energy from waste streams to address the need to increase the national inventory of renewable and mixed energy resources. Resourceful projects on the biogas output optimisation in waste-activated sludge digestion processes and the utilisation of energy sources within the activated sludge process have been under investigation since May 2010.

One such project looks at the utilisation of CO_2 and HCO_3^-, which are produced in the activated sludge and fermentation stages as electron donors during the production of methane. Another project looks at the introduction of microbial cathodes as a replacement of the expensive metallic cathodes in microbial fuel cells (MFCs). These two projects look at the aspect of converting wastewater treatment plants into energy-generating units with the aim of operating the plants from the national grid, and ultimately generating net energy for the grid.

The other waste-to-energy project involves the recovery of oil from waste petroleum sludge by using a mixed culture of biosurfactant-producing organisms. Conventionally, sludge containing oil is incinerated and the residue is dumped at landfill sites. Where recovery is attempted, chemical surfactants with toxic properties are utilised.

This results in a residue with a high chemical oxygen demand (COD), which is not suitable for land applications. The biological process promises to produce high-quality oil that can be utilised in value-adding processes and a cleaner residue with low COD and low toxicity. The quality of the final residue is such that it can be used safely for landfarming operations to improve soil quality for agriculture.

Using the knowledge accumulated during studies on algal blooms and metabolite accumulation rates from eutrophic waters, more work is planned on the recovery of oil from oily sludge and the utilisation of algal species in the recovery of carbon from oil refining and coal gasification processes.

Prof Evans Chirwa *is the incumbent of the Sedibeng Water Chair in Water Utilisation Engineering at the University of Pretoria. He is also a member of the Environmental Engineering Research Group. He is passionate about biological process application for the removal of nutrients and hazardous pollutants from water and wastewater sources. He has recently completed several projects on the removal of toxic metals and organic pollutants from water using pure and mixed cultures of bacteria.*

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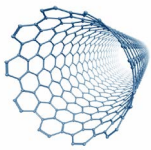
Determining the impact of engineered nanomaterials on the environment

Prof Ndeke Musee

Nowadays, manufactured chemicals in products such as cosmetics, textiles, paints, tyres and medicines are part of everyday life. The increasing production of chemicals has, however, not been matched by an adequate understanding of the risks they may pose to human health and the environment. This phenomenon has been prevalent over the last century and is likely to continue. Notably, the last century has been defined by a wave of new chemicals being introduced into the market, and more are on their way due to scientific breakthroughs and technological advances.

After the turn of the millennium, global commerce started to be defined by the rapid proliferation and production of chemicals that use nanotechnology. The basic building blocks of nanotechnology are engineered nanomaterials (ENMs). Today, ENMs are widely used in many household products. In industrial settings, ENMs are used as catalysts, fuel additives, lubricants, sensor devices and electronics. ENMs are also used for water treatment and in the automotive industry. In fact, according to numerous databases and reports, the use of ENMs has increased drastically since 2005.

This increased use of ENMs is a cause of concern as the potential impact of these materials on humans and the environment is not yet fully known. For this reason, many governments, agencies, academic institutions and manufacturers have developed targeted programmes to systematically examine the potential impact of nanotechnology. As part of a global initiative to understand this potential impact and support environmentally friendly nanotechnology, the Department of Chemical Engineering at the University of Pretoria has initiated research to assess the risk of ENMs in environmental systems. The aim of this research initiative is to provide scientific evidence that supports the long-term safe, responsible and sustainable use of nanotechnology, as envisaged in South Africa's National Nanotechnology Strategy. This strategy was developed and implemented by the Department of Science and Technology (DST) in 2005. Developing the necessary capability requires key components such as human capacity and specialised infrastructure. The research group is located in the Institute for Applied Materials (IAM) of the Department of Chemical Engineering, which is well equipped to synthesise materials with nanoscale dimensions. This is vital if the results are to be useful in a risk assessment framework. A new laboratory facility is being set up in the Department of Chemical Engineering to study the biological interactions with ENMs, and collaborative studies are being carried out with the Department of Genetics in the University's Faculty of Natural and Agricultural Sciences.



Engineered nano-materials are characterised as emerging contaminants of environ-mental concern.

Two doctoral candidates have been conducting research in this field since the beginning of 2015. One of the candidates, Nangamso Nyangiwe, uses computer-based models to determine the most likely descriptors in terms of the inherent physical and chemical properties of ENMs that influence their behaviour in aqueous media. Because of the large number of different ENMs, computer models have an important role to play in terms of carrying out the rapid screening of risks in the first tier of the environmental risk assessment framework.

ENMs are characterised as emerging contaminants of environmental concern, and are therefore likely to be found in very low concentrations in aquatic systems. The ENMs have the potential to exert sub-lethal effects. Ascertaining the toxicity of ENMs requires an understanding of the potential harmful mechanisms. Oxidative stress, inflammation and genotoxicity are among the underlying mechanisms of ENMs' toxicity. According to the Organisation for Economic Cooperation and Development (OECD), genotoxicity is essential

→ *Doctoral candidates have been conducting research in the field of engineered nanomaterials since the beginning of 2015.*

in terms of ascertaining the risks associated with a certain pollutant. Thus, the OECD has recommended certain changes in how ENM genotoxicity should be tested. A doctoral candidate from the Department of Genetics, Ntombikayise Mahaye, is investigating the potential for metal and metal oxide ENMs to cause genotoxicity in invertebrates and free-floating plants. The results will offer insights into how certain aquatic organisms may respond to ENMs by determining the changes in genome expression. For example, such results will give an idea of which genes are up- or down-regulated at a particular time in response to stress caused by ENMs.

So where to from here? Three aspects have to be highlighted. Firstly, the current research to understand the fundamentals underpinning the effects and fate of ENMs is essential as data and knowledge input into the environmental risk assessment framework. Secondly, while it is good to know whether likely adverse effects are associated with ENMs, it is equally important to find mechanisms to mitigate potential adverse effects to the aquatic systems. In the Department of Chemical Engineering, ongoing activities focus on developing a laboratory-based wastewater treatment plant. The model wastewater treatment plant is expected to allow researchers to determine to what extent ENMs can be removed from wastewater. Furthermore, systematic approaches have been adopted to engage various stakeholders in government, regulatory authorities and industry in finding ways of addressing the risks associated with ENMs. These approaches seek to take scientific findings from the laboratory to the marketplace. Finally, given the limited capacity in South Africa in the field of risk assessment of ENMs in aquatic systems, plans to recruit students at master's and PhD level are in place. The IAM also plans to recruit postdoctoral research fellows. This is intended to create a pool of skills that is necessary to support sustainable nanotechnology in Africa.

The question remains, are nanotechnology-based chemicals the last class of chemicals to be introduced into commerce for the benefit of humanity? History paints a different picture, and new forms of chemicals – the risks of which are unknown – will be developed and commercialised in the coming decades. For this reason, developing the necessary tools and techniques to address the potential environmental impacts of ENMs forms a solid basis from which to address the unknown risks of new chemicals in the future.

Prof Ndeke Musee *is an associate professor in the Department of Chemical Engineering and a member of the Environmental Engineering Research Group. He was instrumental in the establishment of a risk assessment laboratory for nanomaterials in environmental systems at the University of Pretoria.*

Atmospheric emissions from clamp kilns in the South African clay brick industry

Dr Gerrit Kornelius

The clamp kiln is the major clay brick production technique in South Africa. It is a primitive technique that consists of a pyramid-shaped formation of dried raw bricks with a layer of combustible material, such as coal, for starting the firing process at the base, with some internal fuel included in the raw bricks.

Globally, it is regarded as an energy-inefficient process with a high probability of air pollution, as the combustion products are simply released into the atmosphere without any mitigation. As such, there has been much discussion in South African environmental circles about the continued use of this technique. However, clamp kiln technology in South Africa has remained competitive, at least in the formal brick production sector, as much larger kilns are used that often contain several million bricks. As a result, the capital cost is lower. This technology produces about 70% of the three million bricks produced in South Africa annually and employs approximately 12 000 people.

The Department of Environmental Affairs has set limits for the air pollutants that may be released from clamp kilns. Sulphur dioxide (SO_2) and particulate matter (PM_{10}) (smoke) were identified as the pollutants caused by clamp kilns. However, the kilns' configuration has made measurement of the emissions difficult, as they are not released through a stack, but from all over the surface of the clamp.

Work carried out by the Environmental Engineering Research Group of the Department of Chemical Engineering during 2012 and 2013 indicated that mass balance calculations were in most cases adequate for calculating SO_2 emissions from the clamp kilns. However, other sources at brickyards also emitted particulate matter and nitrogen oxides, which made assigning these emissions to a particular source difficult. This made it difficult to propose measures for the reduction of air pollution from brick-making facilities.

In collaboration with the South African Clay Brick Association, a study was initiated to design and test a small-scale model kiln that could adequately fire bricks and effectively monitor gaseous pollutants and particulate matter. The effective monitoring of kiln emissions will facilitate the calculation of pollutant emission factors for the kiln and other operations in a typical brickyard. Hence, it would also facilitate the design of air pollution mitigation measures at these facilities.

Model kiln design

The model kiln is situated in an isolated location (in order to limit the influence of external air emission sources) on the site of an existing brickyard. It is designed to simulate the transverse slice of a full-scale clamp kiln that is used for brick-firing in South Africa, but with only 25 000 to 32 000 bricks per firing cycle. It allows the emissions to be routed through a duct so that the released pollutants can be measured.

The design ensures the efficient capture and channelling of flue gas through the stack. The partially closed sides limit gas losses.

Stack monitoring

Model kiln firing and concurrent stack monitoring have been conducted to collect energy balance and emissions data. Input data for different brick factories across South Africa was also collected. This data included data about methods of raw brick processing and packing, the intrinsic properties of "green" bricks (such as moisture content and clay type), the sulphur and energy content, and the type of fuel used.

Results

A physical examination of the fired bricks reveals it to be similar in appearance to bricks fired in full-scale clamp kilns. Combustion efficiency measurements for each batch also show results that are above the normal combustion requirements. These results suggest that the firing process in the model kiln is adequate to produce bricks with similar characteristics to those of normal clamp kilns.

Significant findings from this preliminary study include the following:

Model kiln showing horizontal stack and mesh windscreen.

Packing the model kiln.

- PM_{10} emissions are much lower (by a factor of 5 or more) than the values that are generally assumed.
- The PM_{10} result has implications for dust management around brickyards – especially with regard to emission from road traffic, which may have a much larger impact on particulate matter emissions than the kiln itself.

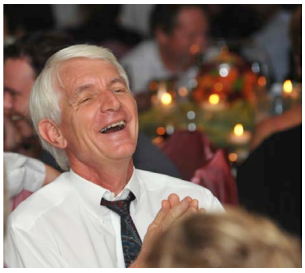
This study may therefore allow optimisation and continued use of the clamp kiln method for brick manufacture.

- A simple mass balance method is sufficient to account for SO_2 emissions from clamp kilns.

The model kiln shows promise as a tool for further optimising firing practices (such as the use of non-traditional fuels to initiate combustion) to reduce energy use and air pollution from this significant sector.

Acknowledgments

This study was partially funded by the South African Clay Brick Association, and its members were generous with their time, products and site amenities.



Dr Gerrit Kornelius *is a senior researcher in the Department of Chemical Engineering and a member of the Environmental Engineering Research Group.*

A social franchising partnership approach to infrastructure maintenance

Dr Kevin Wall

In some areas of South Africa, the failure of infrastructure negates the impact of the development achieved to date. Sometimes, the cause of poor maintenance is an insufficient maintenance budget or the lack of skills to undertake maintenance.

South Africa has exceptionally high unemployment levels and there is substantial evidence that low skills levels contribute to unemployment. Whereas much of South Africa's infrastructure maintenance can be done by people with low skills levels, the need for job creation, especially for people with low skills levels, and for better maintenance, suggests that addressing maintenance backlogs would generate extensive opportunities for skills development and job creation for low-skilled people.

An innovative model

While extensive opportunities for skills development and job creation would be generated by addressing maintenance backlogs, this job creation has to be properly managed, while ensuring the quality and reliability of the maintenance work.

One model that can address this issue is the social franchising partnership model, which borrows from and adapts commercial franchising principles. Social franchising operates on the same premise as commercial franchising, but the focus is on achieving a socio-economic goal, rather than turning a large profit. The model utilises concepts that were formulated by the Council for Scientific and Industrial Research (CSIR), and developed by the CSIR in collaboration with the Water Research Commission (WRC) and the East London-based water engineering contractor Amanz' abantu Services. The success of franchises is based on the replication of success, efficient logistics, as well as a trained and capacitated workforce. A franchise is robust and can ensure products and services of a consistent quality. Franchisees are obliged to adopt the established systems and procedures of the franchisor and to accept the quality control of the franchisor, which results in better quality assurance and greater efficiencies.

Social franchising partnerships are especially suitable for communities with a large under-privileged population in need of services and skills.

This model has already successfully addressed an infrastructure problem that is widely encountered in South Africa. As it was facing a crisis brought about by poor maintenance, the Eastern Cape Department of Education (DoE) agreed to a three-year pilot project for the routine servicing of water and sanitation facilities at approximately 400 schools in the Butterworth education district in 2009. Noticing how effective this intervention was, the nearby district municipality agreed to a pilot project to service household toilets. The DoE, this municipality and other nearby municipalities have since contracted the franchising partnership to do further similar work.

Social franchising partnerships, which have long been established in the health and social services sectors in Europe and Asia, are especially suitable for communities with a large underprivileged population in need of infrastructure services, employment and opportunities to develop their entrepreneurial and technical skills. The concept offers opportunities for linking local economic development and job creation with the provision of basic municipal and community services.

The model provides appropriate training, as well as a quality management system and procedures. The public sector authority's willingness to outsource its

responsibility for routine servicing and its ability to procure, appoint, direct and pay microbusinesses to undertake the work under the guidance of the franchisor, is the franchise's key to success.

The pilot project

Once the DoE had agreed on a project scope, training and operations plans were developed. Local people were invited to come forward and their suitability for training as franchisees was assessed. These trainee franchisees were then assisted to set up their microbusinesses, employing other local people – most of them previously unemployed – and empowering them with learning opportunities and reliable incomes. Under the guidance of the franchisor, these franchisee teams undertook the cleaning and routine servicing of the water and sanitation facilities.

The primary objective of the Butterworth schools' sanitation and water servicing pilot project was to develop and test an outsourcing model that could be used for rolling out similar services to most of the 6 000 public schools across the Eastern Cape's 23 education districts. Without question, it succeeded in achieving this objective.

The following main lessons were learnt from the pilot projects:

- Task-specific concept development (for example, the specifics of the business model, training programme and operations manuals) can only be done by a franchisor who knows the details of performing that task, based on first-hand experience in the same or a similar community.
- Potential franchisees must be chosen on the basis of willingness to work hard and to commit to the business principles.
- Because the service is an essential service, franchising agreements must make provision for the prompt replacement of non-performing franchisees.
- Cash flow problems will quickly put any small enterprise out of business. Careful attention must be paid to resolving procedural issues around the payment process and ensuring prompt payment of invoices submitted by the franchisees.
- To facilitate rapid agreement that the work has been performed according to specifications and that payment can be authorised, tasks must be as standardised as possible and assigned standard prices.

The way forward

In the right hands, this approach ensures quality and reliability of service through training and mentoring. Although the pilot projects both dealt with low-technology sanitation and water infrastructure, there is clearly great potential for social partnerships to undertake the operation and/or maintenance of other infrastructure. Opportunities have been identified in, for example, the maintenance of local electricity reticulation networks, roads maintenance, solid waste collection, the maintenance of stormwater reticulation, and the maintenance of community buildings and public open spaces.

That the average South African citizen or community has little interest in the maintenance or repair of infrastructure that he or she does not regard as his or her own – or which he or she would not see direct benefit in maintaining or repairing – presents an opportunity for social franchising partnerships. Also, the maintenance and repair of household-level infrastructure, such as on-site water and sanitation facilities and solar panels, not to mention the housing structure itself, is often beyond the abilities of households. For example, a study of the usage of rainwater tanks noted that "the maintenance of a rainwater harvesting system is an ongoing regular duty, and knowledge gaps in terms of maintaining the tank exist" (Dobrowsky, Mannel, De Kwaadsteniet, Prozesky, Khan and Cloete, 2014). Accepting that many households either would not or could not undertake the maintenance, "an alternative solution may be to train one or two individuals in the community to supervise the functioning, operation, maintenance and repair of the tanks, instead of rolling out a training programme aimed at the entire household" (Dobrowsky et al. 2014).

In other words, it would often be more effective to assemble workforces from the communities, and then train suitable persons to undertake this work as specialists, rather than expecting the households to do it. Therefore, people or institutions are needed that can carry out the work to the required standard and have the incentive to do so. The social franchising partnership model, providing as it would people skilled to carry out the work to the required standard and with the incentive to do so, is ideal for this.

The driving force behind success is the franchisees' incentive to achieve set standards, get paid when they achieve these standards and grow their own businesses. Systems that are managed by the franchisor reinforce this arrangement, which ensures quality control over the operations, sustainability through economically viable pricing systems and responsible health and safety, and environmental management systems.

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***Dr Kevin Wall**, formerly of the CSIR, is an extraordinary professor in the Department of Construction Economics at the University of Pretoria.*

UP hosts 2015 IAMOT conference

The Graduate School of Technology Management (GSTM) in the Faculty of Engineering, Built Environment and Information Technology at the University of Pretoria was privileged to host the 24th International Conference for the International Association of Management of Technology (IAMOT) in Cape Town in June 2015.

The conference took place some seven years after the 2008 financial crisis. During this crisis, many businesses in countries around the world closed down or were forced to adjust their business models. Other companies survived through unconventional ways of sustaining or exceeding their growth potential. This points to an innovation and technology approach to survival.

Many business leaders see technology as an enabler of innovation. Technology and innovation is considered an intertwined concept. During the economic downturn, companies started using technology, such as innovative shopping experiences that used both physical and virtual shopping channels, for sustainability.

In this context, the theme for the 24th IAMOT conference was "Technology, innovation and management for sustainable growth". The conference aimed to bring together specialists, researchers, scholars and industry participants from all over the world to exchange and share their experiences and latest research results in all aspects of technology, engineering and project management, as well as industrial and systems engineering.

Papers and presentations were delivered on a variety of topics, including asset and maintenance management, emerging technologies and technology management.

Some 416 abstract submissions were received for the 24th IAMOT conference, representing more than 700 authors and 33 countries around the world. More than 198 final full conference papers were accepted and published in the *IAMOT 2015 conference proceedings*.

Xin Yue from Stony Brook University, USA, recipient of the Best Paper Award (co-authored by Guodong Sun), with Dr JO Aje from Thomas Edison State College, USA (centre), and Dr Leon Pretorius (right) from the GSTM at the University of Pretoria.

South African Chapter to improve the delivery of capital infrastructure projects

The South African Chapter of the Construction Industry Institute (CII) was launched at the University of Pretoria on 21 May 2015. Local collaboration with this international consortium of more than 140 leading owner, engineering-contractor and supplier firms in the construction industry, based at the University of Texas, Austin, will measurably improve the delivery of capital facilities in South Africa.

Dr Stephen Mulva, Associate Director for Performance Assessment of the CII.

In South Africa, and Africa as a whole, the quest to improve project management and project management performance on capital projects are strategic focus areas for both the public and private sectors.

As a leader in the project management industry, the CII will enable members to benefit from its global, competitive and market advantages through the research-based, member-driven creation of knowledge and best practices.

One of the largest mega infrastructure projects undertaken in South Africa over the last few years has undoubtedly been the Gautrain Rapid Rail Link. It was therefore appropriate that Jack van der Merwe, CEO of the Gautrain Management Agency, should endorse the South African Chapter of the CII based at the University of Pretoria.

As guest speaker, he touched on the challenges of rolling out mega infrastructure projects in South Africa. Van der Merwe stressed the importance of the life cycle cost of a project, and emphasised the fact that there are a number of external factors that impact on the completion of such a project.

These include factors such as the global environment, which is characterised by change, complexity and competition; and South Africa's political imperatives, which are driven, among other things, by the roll-out of the National Development Plan (NDP).

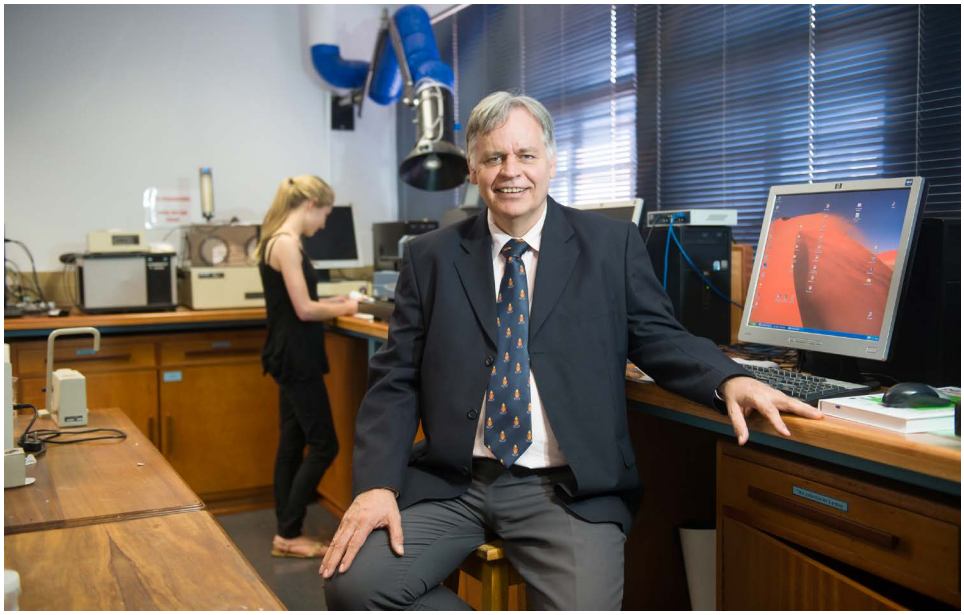
By participating in the activities of the CII, South African capital project owners, government agencies, contractors, suppliers and academia can benefit from the opportunities for collaboration that are created to enhance the business effectiveness and sustainability of the capital facility life cycle through CII research, related initiatives and industry alliances.

Dr Stephen Mulva, Associate Director for Performance Assessment of the CII, expressed his enthusiasm for the launch of the new South African Chapter.

He believes it will contribute to the CII's international offering in terms of knowledge management through the participation of executive-level personnel in the CII's core processes such as research, implementation, education, benchmarking and metrics, breakthrough strategy and globalisation.

Academic achievers contribute to Faculty's excellence

Each year, the University of Pretoria recognises academic excellence through its Academic Achievers' Awards. Awards are presented to exceptional academic achievers, exceptional young researchers, exceptional performance in teaching and innovation, and excellence in community engagement. Researchers at the University who were recently rated by the National Research Foundation (NRF) are also acknowledged at a prestigious event that is held annually. In 2015, the Faculty of Engineering, Built Environment and Information Technology celebrated a number of achievements in the various categories of academic excellence.



→ *Prof Walter Focke.*

Exceptional Academic Achiever

Prof Walter Focke received the Exceptional Academic Achiever Award. This award is made annually to senior academics who have already achieved the status of professor, are regarded highly by their peers, and have consistently excelled in the areas of undergraduate and postgraduate teaching and learning, research, community engagement and administration over a period of time.

Prof Focke is a professor in the Department of Chemical Engineering and Director of the Institute of Applied Materials. He teaches materials science and engineering, and phase equilibrium thermodynamics at undergraduate level, as well as polymer processing and polymer additive technology at postgraduate level.

His research focuses on chemical product design, with the emphasis on carbon materials, polymer additive technology, pyrotechnics and prophylactic malaria control. Various thermal analysis techniques are employed to characterise and control oxidative processes in pyrotechnics, biodiesel and materials such as polymers and graphite.

He has published more than 120 papers in international peer-reviewed journals. His current Scopus h-index is 15 and his publications listed in Scopus have been cited 1 619 times. Google Scholar indicates a total of 1 846 citations with an h-index of 17 and an i10-index of 34.

Teaching Excellence and Laureate Award

Prof Tania Hanekom received the Teaching Excellence and Laureate Award. This is awarded to a nominated project that displays teaching practices with clear purpose and intent, with strong alignment between the different elements in the broader context, that addresses identified needs or gaps with the aim of innovation to optimise teaching and learning. Such a project contributes to best practice in teaching, and displays significant evidence of innovation that addresses the identified challenges.

Prof Hanekom joined the Department of Electrical, Electronic and Computer Engineering in 1999. Her research in biomedical engineering is focused

on the computational modelling of the electrode-neural interface in cochlear implants. In 2005, she was assigned the undergraduate module Microcontrollers (EMK 310), which covered aspects of microcontroller system design.

Owing to the exploding digital device market, it has become essential to equip more engineering graduates with embedded design skills. The lecturing style and assessment strategy were redesigned to support a hands-on approach. To accommodate large student numbers, automated grading software (AGS) was developed to grade students' code answers. The AGS is based on the Microchip MPLAB X SDK test bench and is, to our knowledge, the only automatic grading system in the world that is based on this technology. To create excitement, the practical component of the module was redesigned to enable students to develop autonomous line-following robots that compete at the end-of-semester Race Day. (See article on page 61.)

→ *Dr Martina Jordaan.*

Community Engagement Award

The Community-based Project (JCP) module of the Faculty of Engineering, Built Environment and Information Technology received the Community Engagement Award. This award recognises community engagement as a long-standing and valued tradition in higher education, and is an extensive, high-impact practice in teaching at the University of Pretoria. The criteria for the award are aligned to those of the MacJannet Award, which is administered by the international Talloires Network.

The JCP module is a flagship module of the Faculty and was accredited by the Engineering Council of South Africa (ECSA) in 2006 and 2012. The module received an Education Innovation Award from the University of Pretoria in 2006, was a finalist for the MacJannet Prize of the international Talloires Network in 2010, and won the Marketing, Advancement and Communication in Education (MACE) Excellence Award in the category Integrated Campaigns/Projects and the subcategory Social Responsibility and Citizenship Development in 2014.

In 2014, 1 687 students worked on 556 projects with 394 campus community partners. The YouTube videos produced by the students were viewed by thousands of people in 2013 and 2014 and provided the University with international exposure. Although the scale of the module makes it a challenging endeavour, it is managed very professionally by the lecturer, Dr Martina Jordaan. (See article on page 65.)

→ *Prof Willie Nicol.*

→ *Prof Ramesh Bansal.*

→ *Prof Theo Bothma.*

→ *Prof Ina Fourie.*

NRF-rated researchers

A number of the Faculty's researchers were newly rated by the NRF in 2015. These ratings are based on the quality and impact of a researcher's outputs of the past eight years (2007 to 2014), as evaluated by national and international peer reviewers.

A-rating

An A-rating is awarded to a researcher who is unequivocally recognised by his or her peers as a leading international scholar in his or her field for the high quality and impact of his or her recent research outputs. Prof Andries Engelbrecht, Head of the Department of Computer Science and incumbent of the South African Research Chairs Initiative (SARChI) Chair in Artificial Intelligence, received an A2-rating from the NRF.

B-rating

A B-rating is awarded to a researcher who enjoys considerable international recognition by his or her peers for the high quality and impact of his or her recent research outputs.

Prof Nicola Bidwell received a B3-rating. She is an extraordinary professor in the Department of Informatics. As a leader in human-computer interaction (HCI), she designs technologies to suit the values, livelihoods and knowledge systems of people who are marginalised by urban and Western design. Most of her 100 peer-reviewed publications relate to the communication and knowledge practices of rural and indigenous groups.

Prof Willie Nicol received a B3-rating. He is a professor in the Department of Chemical Engineering. After joining the University in 2001, he established the Reaction Engineering Group in the Department of Chemical Engineering. He is author of more than 50 international peer reviewed publications with a Scopus h-index of 10.

C-rating

A C-rating is awarded to a researcher with a sustained recent record of productivity in the field, and who is recognised by his or her peers as having produced a body of quality work, the core of which has coherence and attests to ongoing engagement with the field, and has demonstrated the ability to conceptualise problems and apply research methods to investigating them.

Prof Ramesh Bansal received a C1-rating. He is a professor and Group Head (Power) in the Department of Electrical, Electronic and Computer Engineering in the School of Engineering, and has more than 25 years' experience in teaching, research and industry. He has published more than 220 journal articles, presented papers at conferences and has contributed to books and book chapters.

Prof Theo Bothma received a C1-rating. He is Head of the Department of Information Science and Chairperson of the School of Information Technology. His teaching and research focus on information organisation and retrieval (including information literacy), web development, electronic publishing and curriculum development.

Prof Ina Fourie received a C1-rating. She is a professor in the Department of Information Science. Her research focuses on information behaviour and information literacy, with specific reference to health-care, current awareness services, and library and information services. She has conducted research on the information behaviour of cancer patients and their families in palliative care, oncology nurses and social workers, as well as a collaborative auto-ethnographic approach to the information-related experiences of caregivers in the context of palliative care.

Prof Martin Olivier received a C1-rating. He is a professor in the Department of Computer Science. He is a certified cyber forensic practitioner (CCFP) of the International Information Systems Security Certification Consortium (ISC2). His current research is focused exclusively on digital forensics, more specifically on providing a suitable scientific basis for digital forensics and promoting greater scientific accountability in the forensic sciences. At a systems level, he is particularly interested in database forensics.

Prof Alta van der Merwe received a C1-rating. She is an associate professor and Head of the Department of Informatics in the School of Information Technology. Her research interests include the design of systems using innovative and new approaches, such as crowd sourcing and content awareness. She focuses on the design of socio-technical solutions by researching enterprise architecture, data science and different theories that support the successful use of technology in organisations.

South Africa's only

A-rated computer scientist

Prof Andries Engelbrecht received an A2-rating from the NRF. He is Head of the Department of Computer Science and the current incumbent of the SARChI Chair in Artificial Intelligence. He is currently the only A-rated researcher in South Africa in the field of computer science.

His research focuses mainly on computational intelligence, and his particular areas of interest are computational swarm intelligence, evolutionary computation, artificial neural networks, artificial immune systems and learning from zero-knowledge using competitive coevolution. Algorithmic models of these phenomena from nature are applied to solve complex optimisation problems, including problems where the search landscape dynamically changes over time, where multiple conflicting objectives have to be optimised simultaneously, and where multiple solutions have to be found and tracked in dynamically changing environments.

His work on particle swarm optimisation (PSO), which was based on models of bird-flocking behaviour, has received significant recognition. Groundbreaking work was done with the development of PSO algorithms to solve binary-valued optimisation problems in continuous-valued space with a fixed small dimension. The first efficient PSO algorithms were developed to solve optimisation problems where solutions are represented using mathematical sets instead of vectors. New PSO algorithms have also been developed to solve dynamic multi-objective optimisation problems, cluster non-stationary data, predict the secondary structure of RNA and perform multiple-sequence alignments. Prof Engelbrecht is well recognised for his work on cooperative and competitive coevolutionary PSO algorithms. His research also provided some of the first theoretical analyses of PSO and its convergence properties. Recent research produced new PSO algorithms to train neural networks in the presence of concept drift and combine evolutionary operators from evolutionary algorithms with PSO.

Prof Engelbrecht recently worked in the field of swarm robotics, developing approaches to control a swarm of simple stimulus-response robots to perform a very complex task. These approaches are based on the foraging behaviour of honey bees and desert ants. His recent work on fitness landscape analysis and its application in determining the complexity of optimisation problems and predicting the level of success of optimisation algorithms is rapidly gaining recognition.

→ *Prof Alta van der Merwe.*

→ *Dr Gazi Mahmood.*

→ *Prof Jaco Dirker.*

→ *Prof David Walwyn.*

Prof Sarma Yadavalli received a C1-rating. He is a professor and Head of the Department of Industrial and Systems Engineering and received his PhD degree from the Indian Institute of Technology in Chennai in 1983. He has published more than 130 research papers on topics including reliability (both software and hardware), queuing, inventory and manpower planning in various international journals.

Dr Gazi Mahmood received a C2-rating. He is a senior lecturer in the Department of Mechanical and Aeronautical Engineering, and his research interests include thermo-fluid sciences. His latest research was conducted on solar heat exchangers and micro gas turbines for manufacturing technology and mining automation.

Prof Anastassios Pouris received a C2-rating. He is Director of the Institute for Technological Innovation and directs his research at the quantitative study of science and technology, scientometrics, evaluations and international benchmarking. He has more than 80 publications indexed in the citation indices of Thomson Reuters. He was nominated for the Derek de Solla Price Award in 2015. This medal is the premier international award of excellence in scientometrics and related fields.

Prof Jaco Dirker received a C3-rating. He is a senior lecturer in the Department of Mechanical and Aeronautical Engineering, and leads a research team of postgraduate students whose work includes experimental and numerical investigations of heat transfer and thermo-fluid optimisation.

Prof David Walwyn received a C3-rating. He is a professor in Engineering and Technology Management in the Graduate School of Technology Management. His research interests cover science policy, research management, performance management in research and technology organisations, renewable energy and health economics. His most significant contribution over the past ten years has been his work on research management and in the pharmaceutical industry.

Y-rating

A Y-rating is awarded to a young researcher (40 years or younger), who has held a doctorate or equivalent qualification for less than five years at the time of publication, and is recognised as having the potential to establish him- or herself as a researcher within a five-year period after evaluation, based on his or her performance and productivity as a researcher during his or her doctoral studies and/or early postdoctoral career.

Dr Marlene Holmner received a Y2-rating. She is a senior lecturer in the Department of Information Science. Her research interests are information ethics, indigenous knowledge, information and communication technology (ICT) for development, the information and knowledge society, institutional repositories, digitisation, mobile technologies and curriculum development. Her work has been published in various academic journals, including the *South African Journal of Libraries and Information Science*, *Information Development* and *Mousaion*.

→ *Prof Martin Olivier.*

→ *Prof Anastassios Pouris.*

→ *Prof Sarma Yadavalli.*

→ *Dr Marlene Holmner.*

Collaboration enables research at the atomic level

The Department of Minerals Science and Metallurgical Engineering will be collaborating with the University of Oxford.

The Department of Materials Science and Metallurgical Engineering will be collaborating with the Department of Materials at the University of Oxford in the United Kingdom to conduct atom probe tomography (APT) experiments to examine the microstructures of some high-pressure commercial pipe steels at the atomic level in order to assess their feasibility for examination using APT and the chemistry of any identified carbides.

APT is a microscopy technique that was invented in 1988 by Prof George Smith, former Head of the Department of Materials at the University of Oxford, together with Alfred Cerezo and Terry Godfrey.

This technique provides 3D atom-by-atom imaging of materials with a uniquely powerful combination of spatial and chemical resolution. Research that can be conducted using APT includes establishing new materials applications, instrumentation and the development of 3D reconstruction and data analysis techniques.

This collaboration with Oxford Materials makes the University of Pretoria the first research institute in Africa to undertake materials research at this level by making use of this unique instrumentation.

Prof Roelf Mostert, Head of the Department of Materials Science and Metallurgical Engineering at UP, is excited about what might be discovered about the microstructures of steels using this technology.

ATKV and the South African Academy for Science and the Arts

Prof Fanie de Beer receives esteemed prize

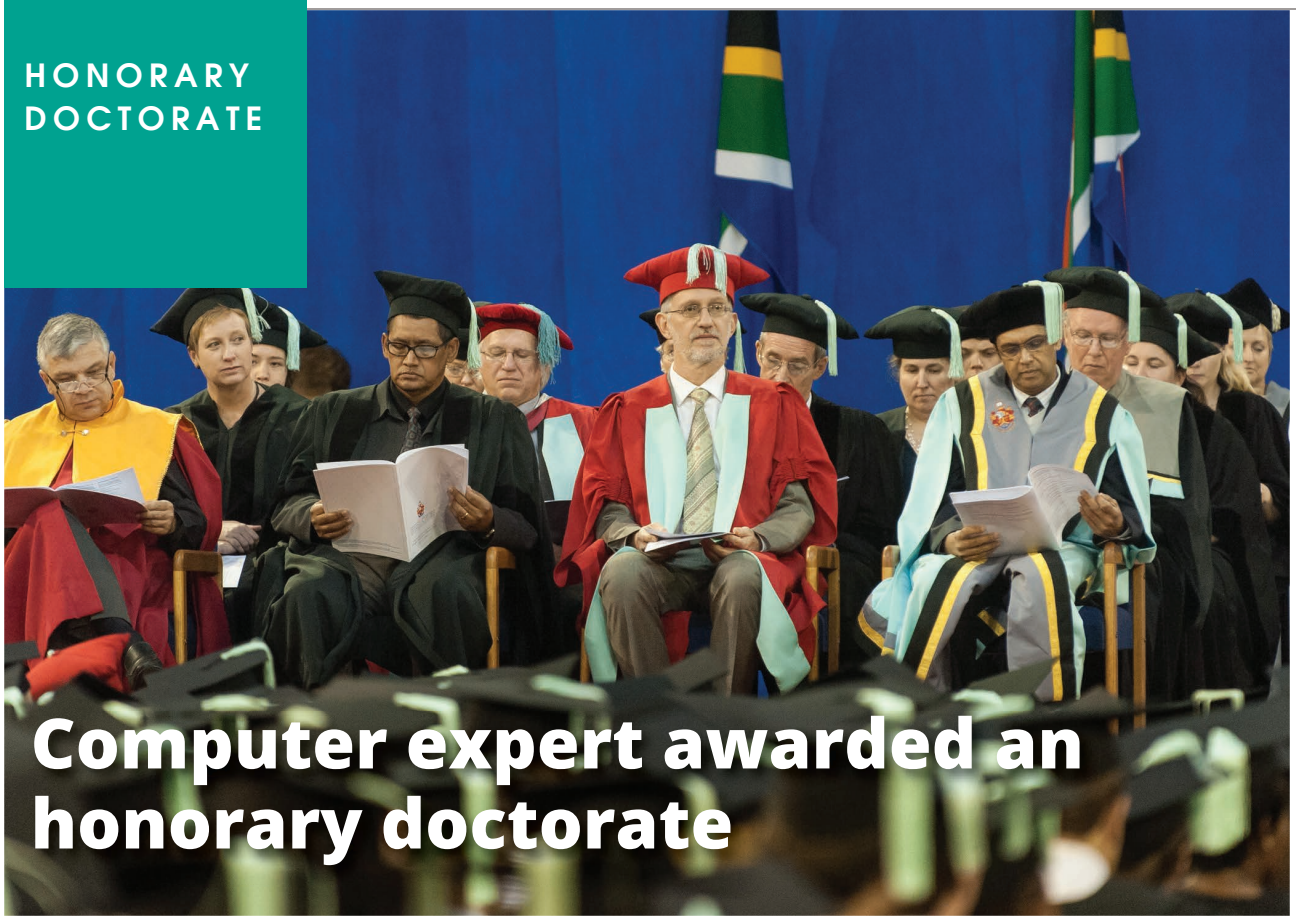
Prof Fanie de Beer of the Department of Information Science received an academic prize from the Afrikaans Language and Culture Association (ATKV) and the South African Academy for Science and the Arts in 2014.

Every year, the ATKV awards R60 000 to six academic articles (R10 000 per article) that were written in Afrikaans and published in accredited journals in a specific year. Four of the prizes go to articles in the humanities and two articles in the natural sciences. The South African Academy for Science and the Arts is responsible for the selection process.

In 2014, the editors of eight accredited journals submitted 16 of the best articles that were published in 2012 to the Academy for selection. Prof De Beer was nominated as one of the four recipients in humanities. His award-winning article, entitled "Die polemologie vir die gees" (The polemology for the spirit) was published in the March 2012 issue of the *Tydskrif vir Geesteswetenskappe* (Journal of Humanities).

Dr Dioné Prinsloo, CEO of the Academy, congratulated Prof De Beer on the high quality of his research and the excellent article emanating from it. The University of Pretoria is proud of Prof De Beer and congratulates him on his achievement.

HONORARY DOCTORATE



Computer expert awarded an honorary doctorate

The University of Pretoria awarded an honorary doctorate in Computer Science to Italian researcher Prof Marco Dorigo in April 2015. He has been recognised for his study of the complex social behaviour of ants and application of his findings to computer science in order to solve difficult combinatorial optimisation problems.

His so-called ant colony optimisation algorithm is capable of solving computational problems by finding the shortest paths through graphs in the same way that ants, using only pheromones to navigate, can find the shortest path from their nest to a food source. He described the conception of the algorithm as follows: "I imagined a bunch of simple artificial agents imitating real ant behaviour to solve difficult mathematical problems. Although it sounded like a crazy idea then, today it is accepted even by professional theoretical computer scientists and software engineers."

Prof Dorigo is Research Director of the Belgian National Fund for Scientific Research (NFSR) and Co-Director of Intstitut de Recherches Interdisciplinaries et de Developpements en Intelligence Artificielle (IRIDIA), the artificial intelligence laboratory of the Université Libre de Bruxelles. His current research interests include swarm intelligence, swarm robotics and metaheuristics for discrete optimisation.

He is a fellow of the Institute of Electrical and Electronics Engineers (IEEE), the Association for the Advancement of Artificial Intelligence (AAAI) and the European Coordinating Committee for Artificial Intelligence (ECCAI). He has received many international prizes in recognition of his scientific contributions.

Prof Dorigo encourages computer science graduates to consider research and science as possible alternatives to a corporate career.

He says that to be a successful researcher or scientist, one needs to be creative, self-confident and passionate about one's work. He encouraged graduates to make a difference in the lives of those who are less privileged. "We should never forget that we are among the lucky ones and that we should be at the service of [those who are] less fortunate. Do not forget to spend part of your energy building a better world with fewer inequalities and less injustice," he concluded.

HONORARY DOCTORATE

University of Pretoria honours renowned engineer

One of the most-cited authors in the field of engineering, Prof Adrian Bejan, received an honorary doctorate in Engineering from the University of Pretoria in April 2015. He received the degree in recognition of the enormous scope and tremendous contributions he has made in the fields of thermodynamics, heat transfer and applied physics.

Prof Bejan holds a PhD in mechanical engineering and has pioneered numerous original methods in thermodynamics and applied physics, such as the constructal law of organisation and evolution in nature, entropy generation minimisation, scale analysis of convection, designed porous media, heat lines and mass lines. His research covers a wide range of topics in thermodynamics, heat transfer and fluid mechanics.

He was a lecturer at Massachusetts Institute of Technology, a Miller postdoctoral fellow at the University of California, Berkeley, and an assistant and associate professor at the University of Colorado, Boulder. In 1984, he joined Duke University as a full professor with tenure. In 1989, he was awarded the chair of JA Jones distinguished professor of mechanical engineering at Duke University.

Prof Bejan is the author of over 600 peer-refereed journal articles and 28 books, including *Design in nature* (Doubleday, 2012), *Shape and structure, from engineering to nature* (Cambridge University Press, 2000), *Design with constructal theory* (Wiley, 2008), *Entropy generation minimization* (CRC Press, 1996) and *Constructal theory of social dynamics* (Springer, 2007). His treatises on *Advanced engineering thermodynamics* (Wiley), *Convection heat transfer* (Wiley) and *Convection in porous media* (Springer) are now in their fourth editions and are used as graduate textbooks at universities around the world. In 2001, the International Statistical Institute (ISI) ranked him among the 100 most-cited authors in engineering (all fields, all countries, living or deceased). His h-index is 54.

He has been awarded 17 honorary doctorates from universities in 11 countries, including the Swiss Federal Institute of Technology (2003), the University of Rome La Sapienza (2009), Université Henri Poincare Nancy (2001) and INSA Lyon (2014). He is a member of the Academy of Europe and an honorary member of the American Society of Mechanical Engineers, the Romanian Academy and the Moldova Republic Academy of Sciences. Prof Bejan describes engineering as a field of science that allows creativity, which can result in the creation of things that do not yet exist. He describes science as "a story that evolves to become better".

Tata Africa Scholarship

Young electronic engineering graduate is making her mark

Two young female postgraduate students at the University of Pretoria are proving that engineering has long ceased to be a male-dominated field. In recognition of their outstanding academic and research abilities, Shruti Lall (above) received the Tata Africa Scholarship in the category for master's degree study, while Marilize Everts (see article on opposite page) received the scholarship in the category for PhD study.

Lall is a student in electronic engineering, who received the Tata Scholarship in August 2015. This award forms part of the Department of Science and Technology (DST) South African Women in Science Awards.

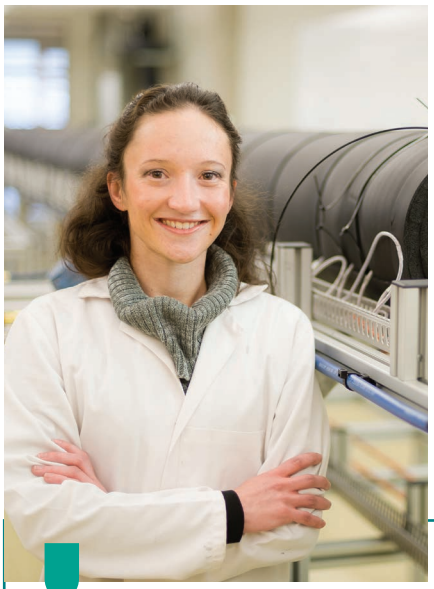
In addition to this prestigious award, Lall has also received a Fulbright Scholarship to continue her studies in the USA in 2016. This scholarship programme will allow her to do research and study at a university or other appropriate institution in the USA for one year or longer. Although she has not yet been placed at a specific university, Lall is looking forward to continuing her studies abroad next year.

In 2013, she completed her BEng (Computer Engineering) degree cum laude at the University. She then went on to obtain her BEng (Hons) degree cum laude in 2014.

She has a sterling record of exceptional performance, having received a silver merit award in Computer Engineering in her first year of undergraduate study, and a gold merit award in her second year. She has also been a recipient of the Sentech Broadband Wireless Multimedia Communications (BWMC) bursary since her second year, and appeared on the Dean's Merit List for the entire duration of her undergraduate studies.

Lall is currently pursuing master's research in wireless network security. Her research investigates the optimal placement and power allocation of protective jammers in wireless networks and involves the development of a security model, comprising protective jammers optimally placed to afford wireless networks protection against malicious devices seeking to obtain confidential information.

The Tata Africa Scholarship forms part of the DST South African Women in Science Awards, and recognises outstanding academic and research skills.



Tata Africa Scholarship

Young mechanical engineer earns exceptional recognition

The Department of Mechanical and Aeronautical Engineering at the University of Pretoria provides a special and unique opportunity for students to prepare themselves for the demands of their future work environment. This ensures that its students are recognised for their excellent academic and research abilities.

Marilize Everts, a doctoral candidate, received the Tata Africa Scholarship in the category for PhD study for her outstanding academic and research skills. The scholarship was awarded as part of the South African Women in Science Awards (part of the efforts of the DST to increase the number of female scientists and researchers in the country).

Everts completed a BEng (Mechanical Engineering) degree with distinction at the University of Pretoria in 2012 and was the top student in the School of Engineering in that year. In 2013, she completed her BEng (Hons) degree in mechanical engineering with an average of 90% (with distinctions in all eight modules), and in 2014 she obtained 99% for her master's degree research. Her research focuses on the heat transfer and pressure drop characteristics of developing flow in smooth and rough tubes in the transitional flow regime.

Leader in heat transfer receives Chairman's Award

→ *Prof Josua Meyer.*

The Faculty of Engineering, Built Environment and Information Technology is proud to announce that Prof Josua Meyer, Head of the Department of Mechanical and Aeronautical Engineering and Chairman of the School of Engineering, was awarded the South African Institution of Refrigeration and Air-conditioning (SAIRAC) Chairman's Award.

He was recognised for his seminal research contributions over the past 25 years in the field of heat transfer with specific reference to his understanding and quantification of heat pumps, the optimum geometries of enhanced tubes, and the influence of different types of inlets on transition and condensation heat transfer at different inclination angles.

All of this work is directly related to the development of more energy-efficient equipment, which is widely used in the air conditioning and refrigeration industry today.

Prof Meyer has been recognised by the National Research Foundation (NRF) as a B-rated researcher.

Improving transportation through railway engineering knowledge and skills

Transnet currently invests more than R300 billion in infrastructure development to rejuvenate the economy, create jobs and address poverty and inequalities. Of this amount, R201 billion has been assigned to Transnet Freight Rail to expand its rail infrastructure to create capacity and increase cargo volumes.

According to the 2014 Budget Speech, government planned to spend approximately R22.9 billion to upgrade commuter rail services over three years. Rail services would be emphasised, making this the ideal time to upgrade engineers' railway engineering knowledge and skills. With the cooperation of world-class experts, the Faculty of Engineering, Built Environment and Information Technology offers a wide variety of high-quality short courses that will benefit railway engineers.

The Transnet Chair in Railway Engineering in the Department of Civil Engineering relaunched its Introduction to Multi-disciplinary Concepts in Railway Engineering course in January 2015 to celebrate its 23 year-long relationship with Transnet. The course was presented at the Innovation Hub in Pretoria.

Topics such as train authorisation, train vehicle, train track and train traction technology were covered during the week of 26 to 30 January 2015. The relaunch of the course was celebrated with a cocktail function on 29 January, which was attended by course participants and presenters, as well as a number of delegates from Transnet. At the function, Prof Sunil Maharaj, Dean of the Faculty of Engineering, Built Environment and Information Technology, highlighted the collaboration between the University and Transnet as a sterling example of how academia can serve industry by offering globally competitive courses to meet its needs.

The Transnet Chair in Railway Engineering was established at the University of Pretoria in 1992 with the sponsorship of Transnet Freight Rail. The Chair not only focuses on research and development, but also on graduate training, continuing education and technical support.

The chairholder is Prof Hannes Gräbe, a civil engineer with 20 years' experience in track technology, track geotechnology, advanced laboratory testing, field investigations, maintenance models and the numerical analysis of track structures.

This is the ideal time to upgrade engineers' railway engineering knowledge and skills.

The Transnet Chair in Railway Engineering has a strong focus on track infrastructure research and is active in the following fields:

- Conventional ballasted and non-conventional track structure performance
- The numerical modelling of track structures and vehicle/track interaction
- Formation failure, repair and investigation
- Standard laboratory testing of rails, fasteners, sleepers and ballast
- The development of track deflection measurement systems
- The development of non-destructive track condition monitoring technologies (for example, ground-penetrating radar)
- Stress and strain measurement systems
- The measurement of stress-free temperature in continuously welded rails
- Track maintenance models
- Maintenance limits and condition monitoring
- Asset management and maintenance management strategies and philosophies

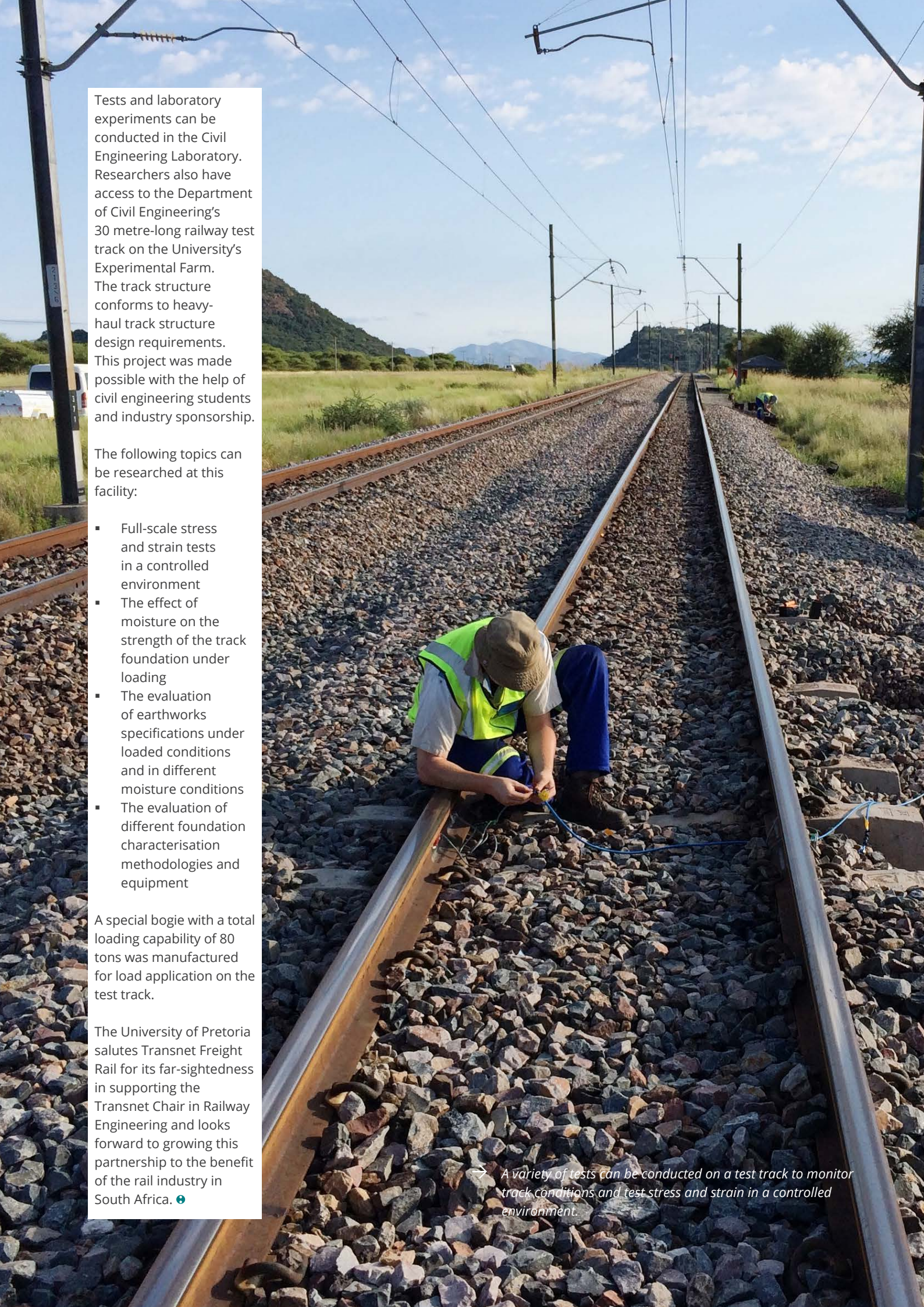
Tests and laboratory experiments can be conducted in the Civil Engineering Laboratory. Researchers also have access to the Department of Civil Engineering's 30 metre-long railway test track on the University's Experimental Farm. The track structure conforms to heavy-haul track structure design requirements. This project was made possible with the help of civil engineering students and industry sponsorship.

The following topics can be researched at this facility:

- Full-scale stress and strain tests in a controlled environment
- The effect of moisture on the strength of the track foundation under loading
- The evaluation of earthworks specifications under loaded conditions and in different moisture conditions
- The evaluation of different foundation characterisation methodologies and equipment

A special bogie with a total loading capability of 80 tons was manufactured for load application on the test track.

The University of Pretoria salutes Transnet Freight Rail for its far-sightedness in supporting the Transnet Chair in Railway Engineering and looks forward to growing this partnership to the benefit of the rail industry in South Africa.



A variety of tests can be conducted on a test track to monitor track conditions and test stress and strain in a controlled environment.

ACEIE seals collaboration with UNESCO

The African Centre of Excellence for Information Ethics (ACEIE) signed a Memorandum of Understanding (MoU) with the South African National Commission (SA NatCom) of the United Nations Educational, Scientific and Cultural Organisation (UNESCO) on 29 July 2015. Mr Carlton Mukwevho, Secretary-General of SA Natcom, and Prof Sunil Maharaj, Dean of the Faculty of Engineering, Built Environment and Information Technology, signed the agreement on behalf of their respective organisations.

Celebrating the signing of the MoU between the ACEIE and UNESCO: front (from left): Prof Sunil Maharaj, Dean of the Faculty of Engineering, Built Environment and Information Technology, Carlton Mukwevho, Secretary-General of SA NatCom, Reabetswe Thole of SA NatCom and Coetzee Bester, Director of ACEIE; back (from left): Prof Theo Bothma, Head of the Department of Information Science, Andile Mgweba of the Department of Telecommunication and Postal Services, Gabriella Bettoni of the ACEIE, George Molepo, Communication and Information Programme Officer of SA NatCom, and Daniella Bettoni, Rachel Fischer and Benson Lechaba of the ACEIE.

The MoU follows on a history of collaboration between UNESCO and the ACEIE since the Centre's establishment in 2012, and commits UNESCO to provide funding for five regional projects until December 2015. This marks the occasion of another contract guaranteeing successful collaboration opportunities that will strengthen the ACEIE's current interaction with 80 institutions across 19 African countries.

The ACEIE is housed in the Department of Information Science, and its main objectives are to act as a facilitator, to conduct research in information ethics locally and internationally, and to coordinate awareness and knowledge-enhancing activities locally and across the continent.

The five projects sponsored by UNESCO support these goals.

Project 1: Learners with disabilities, cyberbullying and sexting

This project formed part of the ACEIE's Digital Wellness Programme and Inclusion of Disability Awareness activities between 23 and 26 June 2015 in Cape Town, South Africa. It focused on raising awareness on cyber safety issues affecting people with disabilities.

Project 2: Community rollout of information ethics within a volunteer programme

In July 2015, a volunteer programme, championed by Intel as a UNESCO-recognised partner, was launched in Nairobi, Kenya. Furthermore, an Information Ethics teaching and curriculum conference was hosted by the Kenyatta University.

Project 3: Information Ethics school curriculum development

The ACEIE, in collaboration with the University of Pretoria, Intel and the Department of Basic

MoU

Education, is participating in research to develop a school curriculum specifically targeted at basic education and community training. A workshop on this development project was held in Pretoria in July 2015.

Project 4: Policy design workshop: digital safety and wellness in schools

Together with the National Science and Technology Forum and the Civilian Secretariat for Police, the ACEIE hosted a Digital Safety and Wellness Policy design workshop in Kempton Park on 21 August 2015. At the workshop, security and safety issues for the public sphere, as well as for the cyber sphere, were highlighted.

Project 5: Conference on Digital Wellness in Africa

A three-day conference on digital wellness in Africa is being held at the University of Pretoria in November 2015. It will combine the theme of digital wellness with the UNESCO communication and information sector programmes of the Information for All Programme (IFAP) and the International Programme for the Development of Communication (IPDC), and will be co-hosted by the Institute for the Advancement of Journalism.

The African Centre of Excellence for Information Ethics (ACEIE)

Coetzee Bester heads up national IFAP Committee

The Director of the African Centre of Excellence for Information Ethics, Coetzee Bester, was elected as the Chairperson of the National Information for All Programme (IFAP) Committee on 15 October 2014.

This coincided with the establishment of the National IFAP Committee on the same day.

Bester has been involved in the African Network for Information Ethics (ANIE) and the ACEIE for some years, and has been an invaluable partner in several activities related to IFAP at national, regional and international level. Conversely, the support of the UNESCO structures related to information ethics has enabled the ACEIE to do groundbreaking research that has benefited more than 50 academic and training institutions in Africa who are members of ANIE.

Established in 2001, IFAP is an intergovernmental programme of UNESCO. It serves as a platform for international policy discussions, cooperation and the development of guidelines for action with regard to access to information and knowledge. Member states receive support in developing and implementing their national information policy and strategy frameworks.

The National IFAP Committee consists of members from government, as well as non-governmental and civil society organisations. Its work focuses on IFAP's six priority areas.

The Committee's aim is to support the development and implementation of information policy strategies and frameworks in South Africa. It will also contribute to strengthening IFAP's contribution in Southern Africa. A regional meeting of Southern African national IFAP committees took place in April 2015.

The ACEIE will provide office space to the South African National IFAP Committee.

Signal processing technique ready for commercial testing

Earlier in 2015, a doctoral degree candidate at the University of Pretoria's Centre for Asset Integrity Management (C-AIM) developed a new signal processing technique for the vibration monitoring and testing of turbomachinery. Now, C-AIM aims to create industry partnerships to develop this technique to maturity and commercialisation.

Over the last two years, Dawie Diamond, who conducts research in mechanical engineering, developed the new statistical signal processing technique for blade-tip timing measurements. He uses the blade-timing approach in the analysis of the synchronous vibration of turbine blades during a constant turbine shaft speed.

Blade-tip timing is used to monitor blade vibration and uses probes of various designs to detect the arrival time of individual rotor blades at a number of points around the rotor casing. The technique forms part of several online, non-intrusive condition monitoring techniques that focus on vibration signals or pressure fluctuations that are observed in turbine blade testing.

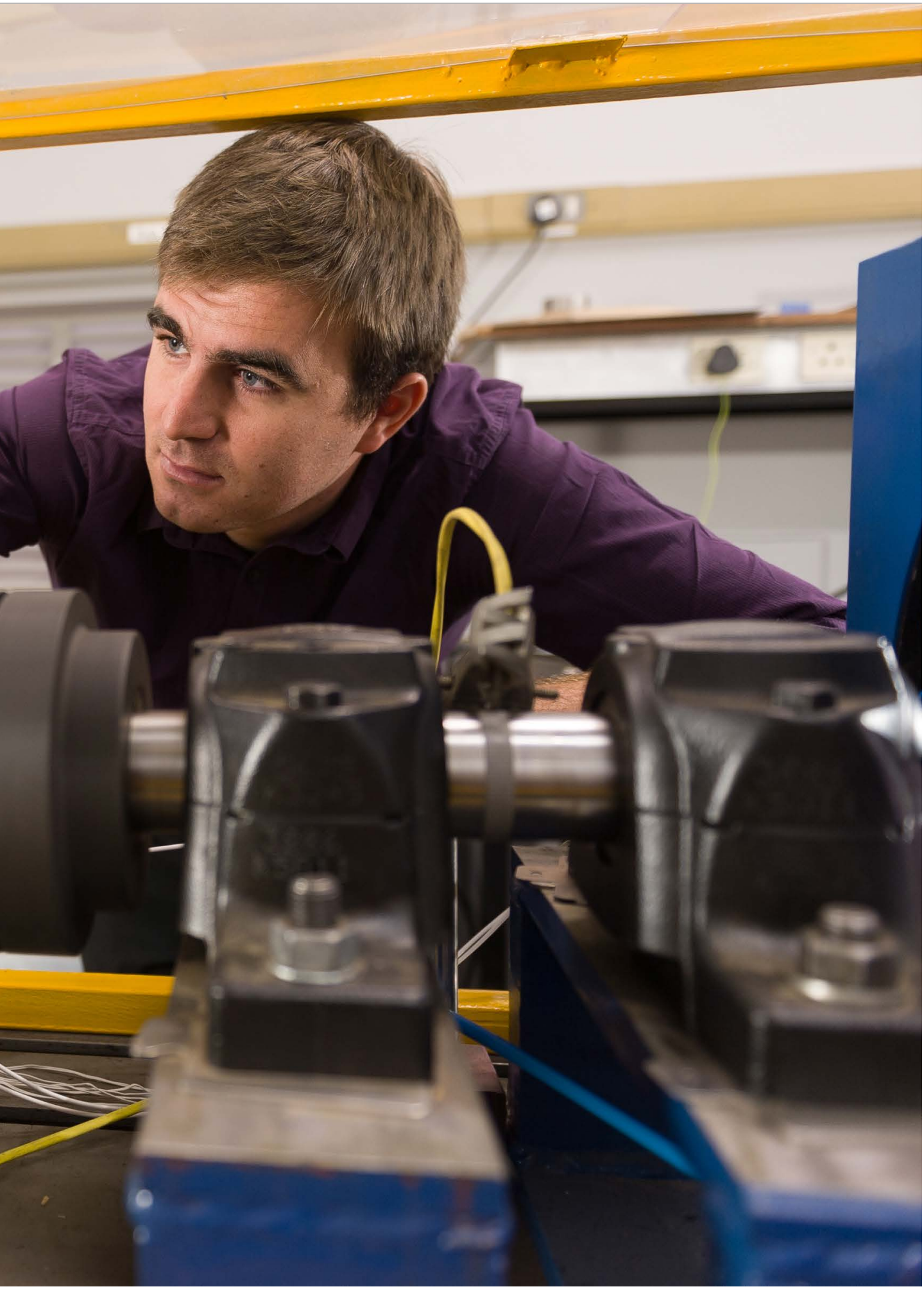
Diamond explains that this vibration is one of several vibration conditions of turbomachinery, which can include flutter that occurs when there is aerodynamic instability and synchronous vibration.

The technique was successfully used in the Sasol laboratory from July to November 2014, with several recorded and verified successes on a laboratory-scale turbomachine blade-vibration test setup. The technique was also tested against other published methods, with the results providing an error of only 0.2% – a significant increase in accuracy – whereas another testing method provided an error of about 5 to 6%.

Despite these favourable results, he acknowledges the challenges in testing practicalities, which can only be verified on industry-sized turbomachinery, hence the need for access to industry turbines to conduct active field research and complete the technique's methodologies.

Prof Stephan Heyns, Director of C-AIM, concludes that: "The research work developed to such an extent that we believe we have a solution, which, in collaboration with industry partners, can be brought to commercial feasibility." He believes that this will be a leap forward in understanding the conditions of turbomachinery.

Prof Heyns expects field testing to start within the next two years and stresses that, as turbomachinery (particularly turbines) lies at the heart of any power production process, it is crucial to ensure the integrity of these machines.



New partnership opens doors

One of the strategic objectives of the Faculty of Engineering, Built Environment and Information Technology is to establish new partnerships with national and international research, educational, funding and other organisations. In August 2014, the Department of Electrical, Electronic and Computer Engineering signed a Memorandum of Understanding (MoU) with Powertech, a wholly owned subsidiary of Altron (Allied Electronics Corporation Limited).

Celebrating the signing of the partnership agreement are Prof Sunil Maharaj, Dean of the Faculty (far left), Prof Gerhard Hancke, Head of the Department (third from left) and Prof Ramesh Bansal, Head: Power Systems Engineering Group in the Department (far right).

Powertech is focused on delivering advanced technologies for the creation, management, distribution, storage and use of electricity across industries. The company's core business includes the reliable delivery of high-quality technical equipment, support and engineering expertise to support demanding client requirements across a range of specialist applications. Dr Raj Naidoo, a senior lecturer in the Department and a registered professional engineer, will be overseeing students' progress.

The mission of this valuable four-year partnership is to participate in forefront research activities in power and energy research, and to deliver world-class research and educational outputs for the benefit of Powertech, the University, and the power and energy industry in general.

The partnership aims to accomplish the following:

- Promote study and research in the field of power and energy systems, products and services.
- Enhance interaction between academic institutions and the industry in general, and specifically between the University of Pretoria and Powertech.
- Contribute to education and teaching in the fields of power systems, energy systems and electrical design at an undergraduate and, possibly, postgraduate level.
- Aid human capital development and the development of skills in the power and energy area.

Powertech will initially fund undergraduate student bursaries in the fields of electrical and mechanical engineering. At Powertech's discretion, this may be extended into a Power Systems Chair with an administrative assistant, and the development of postgraduate modules and bursaries. Students' progress, as well as development and outputs, will be reviewed annually.

A smart perspective on electricity

The University of Pretoria is paving the way for new approaches to solving South Africa's energy crisis. Its Smart Grid Lab in the Department of Electrical, Electronic and Computer Engineering offers a fresh approach to smart grid research that will empower end users and deliver savings and benefits to utilities and municipalities. These benefits will be realised across the industrial, commercial and residential sectors.

The electricity grid refers to a network of transmission lines, substations and transformers that deliver electricity from the power plant to homes and businesses. Successful smart grid technology should be able to cope with all the demands of the digital era, as well as automate and manage the increasing complexity of and need for electricity in the 21st century. A smart grid is a modernised electricity grid that uses analogue or digital information and communication technology to gather and act on information. Customers will receive better service and lower electricity rates. This new type of grid will consist of controls, computers, automation and new equipment.

The Smart Grid Lab delivers high-quality research, products, services and capabilities that fill the widening gap between the end users and electricity suppliers across African markets. Some of the practical applications and opportunities for research include renewable energy integration, smart prepaid metering, advanced metering infrastructure security and active network management.

The University's Smart Grid Research Group collaborates with the Smart Grid Programme Manager at the South African National Energy Development Institute (SANEDI), Dr Minnesh Bipath. The research group is led by Dr Raj Naidoo, a senior lecturer in power and energy systems engineering, and Director of Enermatics Energy and Stellenbosch Wind Energy Technologies (SWET). The other two members of the research group are able to contribute their vast experience to this cutting-edge research.

Prof Ramesh Bansal, who heads the Power Systems Engineering Group at the University of Pretoria, has more than 22 years of teaching, research and industrial experience, while Prof Xiaohua Xia is Director of the Centre of New Energy Systems (CNES), as well as the National Hub for Postgraduate Programme in Energy Efficiency and Demand-side Management Hub at the University of Pretoria.

Head of Department recognised for lifelong service to profession

Prof Sarma Yadavalli, Head of the Department of Industrial and Systems Engineering, has received the 2015 Industrial Engineering and Operations Management (IEOM) Distinguished Educator Award. The award was made in recognition of his outstanding lifelong service, dedication to education and outstanding support, as well as service to the industrial engineering and the operations management professions.

Prof Yadavalli received the award at the 2015 IEOM Conference at Hyatt Regency in Dubai on 4 March 2015.

Prof Sarma Yadavalli (left) receives the Distinguished Educator Award from Prof Abdur Rahim of the University of New Brunswick (centre). Looking on is Ms Resh Plaha of Crystal Quality UK Ltd (right).

The IEOM Society recognises educators, researchers and professionals for their significant contribution through teaching, research and publication, service, innovation or leadership in the field of industrial engineering and operations management.

Prof Yadavalli obtained a BSc (Mathematics) degree from Andhra University, India, in 1975, followed by a master's degree in Statistics from Osmania University in 1978 and a PhD from the Indian Institute of Technology in 1983.

Prof Yadavalli started his career as a research scholar and tutor at the Indian Institute of Technology in 1978. From 1983, he lectured at a number of tertiary institutions, including Bendel State University in Nigeria, the University of the West Indies in Jamaica and the National University of Lesotho. He joined the erstwhile University of Transkei in 1991 and the University of the North in 1994, after which he joined the University of South Africa in 1997.

Prof Yadavalli came to the University of Pretoria in March 2002 as a professor in the Department of Industrial and Systems Engineering. He was appointed Head of Department in 2010.

Prof Yadavalli has reviewed the study programmes of the Department of Statistics at the University of Botswana as an external reviewer.

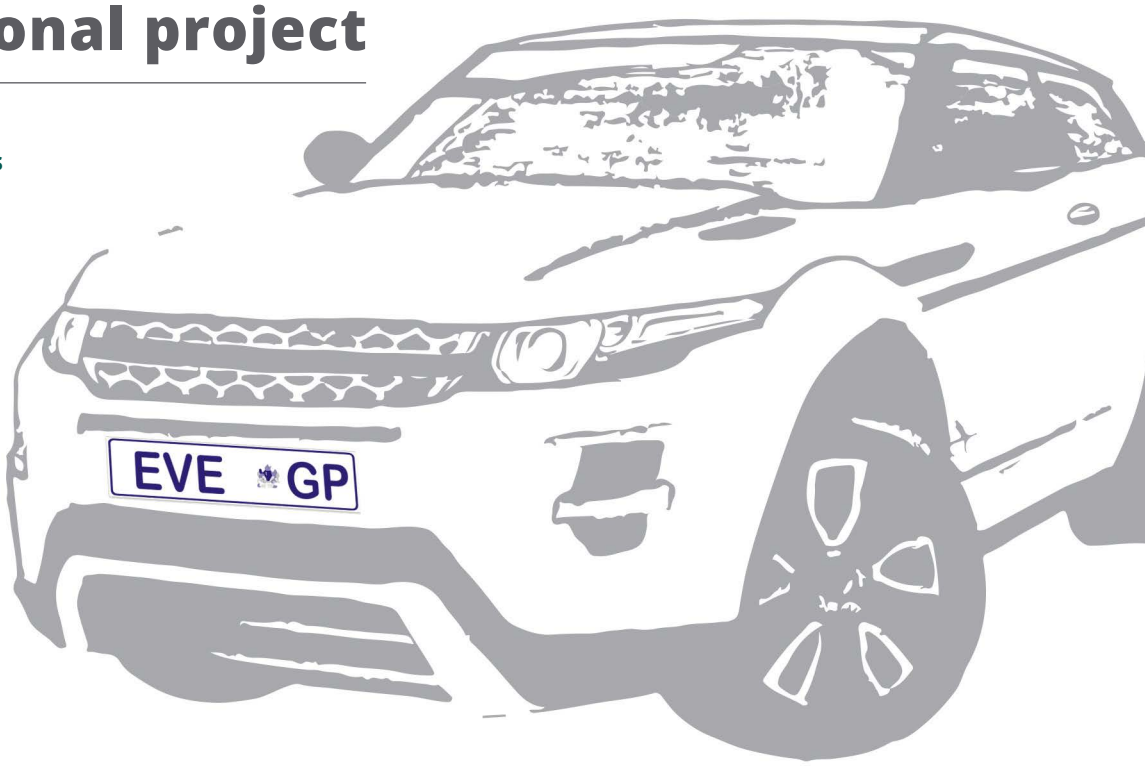
He has presented several papers at national and international conferences and is a member of a number of professional organisations, including the Southern African Institute of Industrial Engineers (SAIIE), the Society for Quality, Reliability and Operations Management, and the International Statistical Institute.

He has a C1-rating from the National Research Foundation (NRF)

Prof Yadavalli also received the lifetime achievement award from the Society for Quality, Reliability and Operations Management at the International Conference on Quality, Reliability and Infocom Technology (ICQRIT) held at the Indian National Science Academy in December 2006.

This award was made in recognition of his contributions in industrial engineering and reliability theory.

Vehicle Dynamics Group participates in international project



Innovation technologies in ground vehicle engineering require strong interdisciplinary and intersectoral investigations with an international dimension. In light of this, a consortium of 12 partners from industry and research institutions has started the Innovative Engineering of Ground Vehicles with Integrated Active Chassis Systems project, also known as Project EVE. The Vehicle Dynamics Group (VDG) in the Department of Mechanical and Aeronautical Engineering participates in this project and represents the University of Pretoria as the project's only South African university.

The project aims to develop and improve innovative vehicle components, such as integrated chassis controller targeting, simultaneous improvements in vehicle stability and energy efficiency, new hardware subsystems for brakes, active suspension and tyre pressure control for on- and off-road mobility, as well as remote network-distributed vehicle testing technology.

The project is funded by the European Community Horizon 2020 Framework Programme Marie Skłodowska-Curie actions (under grant agreement no. 645736). The EVE consortium is coordinated by Ilmenau University of Technology (Germany) and includes institutions and organisations such as Tenneco Automotive Europe (Belgium), ITAINNOVA Instituto Tecnológico de Aragón (Spain), Delft University of Technology (Netherlands), dSPACE GmbH (Germany), SKF Automotive Development Centre (Sweden/ Netherlands), Chalmers University of Technology (Sweden), Virginia Tech (USA), Gerotek (South Africa) and ESTEQ Ltd. (South Africa).

The project's activities will span three years and will be carried out through comprehensive vehicle dynamics simulations in diverse software environments, and a combination of vehicle testing on state-of-the-art dynamometrical test rigs and proving grounds in Germany and South Africa. At the centre of the experimental activities is a high-tech instrumented vehicle demonstrator that is used for the development and evaluation of the novel chassis control system. It is housed at the Ilmenau University of Technology. As an innovation-oriented project, EVE will develop a number of technologies for automotive chassis engineering ready for immediate industrial implementation after the conclusion of the project.

The project's targets will be achieved with intensive networking measures, which cover knowledge transfer and experience sharing between participants from academic and non-academic sectors, the professional advancement of the consortium members through intersectoral and international collaboration, and secondments.

For more information on Project EVE, go to http://eve-project.eu/

TuksBaja makes it count

The TuksBaja team comprises a group of dynamic students from the Department of Mechanical and Aeronautical Engineering whose cars have held their own in many races and static design events. The students build their own off-road vehicles – constantly tweaking and improving different parts to give them the edge in the endurance race and earn them maximum marks in the static design event.

Each year, the team attends a Baja Camp, where they adjust and test their cars. In 2014, the camp took place on a farm near Villiers in the Free State from 5 to 7 September. Owing to the late arrival of Car 55 from customs after its trip to the USA, where it did the team proud earlier in 2014, assembly could not take place in the labs as planned. The team had to assemble Car 55, now Car 5, and Car 2 on the farm. Nevertheless, they pulled through and got both cars ready in time for some mock manoeuvrability trials. The next day, the team could reap the benefits of their hard work and push the cars to their limits. This allowed them to experience the excitement of being behind the wheel and gave them a sense of accomplishment. They were also able to determine which components needed replacing or design improvements, which they could concentrate on in the weeks leading up to the Sasol Baja SAE Competition, which was held at Gerotek Testing Facility on 24 and 25 October 2014.

Following the camp preparation, plans for the next seven weeks leading up to the Sasol Baja SAE Competition had to be made. With the competition looming, the team kicked into overdrive and the cars started to take shape once again. While finishing the cars' assembly, the team performed normal pre-race performance tests. Both cars were rigorously tested in order to ensure optimal performance during the race. Thanks to the team's commendable efforts, both cars were ready to race on 24 October 2014.

In preparation for the Sasol Baja SAE Competition, a few new improvements were made to Car 5, the prototype car. These developments included the implementation of a four-wheel steering system, which was designed by senior team member Tokologo Komana. The team used the four-wheel steering for Day 1 of the competition. Everyone was impressed, as it was a first for the Sasol Baja SAE Competition. However, as with any prototype, the system had its flaws and the team opted for the conventional steering system on race day. The new front upright design to remove the rod-end restriction was successfully implemented on the car.

The first day of the competition comprised the static events category and the safety inspection, followed by the dynamic events category. The static judging for both cars went well, as Car 2 won best design score, as well as the best cost report and second-best design report.

Car 5 achieved the best design report. After both cars had sailed through the inspections, they excelled at the acceleration, manoeuvrability and skid pull challenges.

The second day was an early morning for some of the team members, as the four-wheel steering system on Car 5 had to be replaced with the old steering system. Nonetheless, the team completed the car in time and it could race as planned.

Unfortunately, Car 5's race did not go very well, as there were issues with under-steer and broken bolts on the front right wheel's bead-locker, but the excellent pit crew effectively and efficiently got the car back on the track. Car 2 placed fourth in the race.

Construction economics bids farewell to Head of Department

The Department of Construction Economics in the School for the Built Environment is a leader in the provision of well-prepared practitioners in the fields of construction and property development in the private and public sectors, locally and abroad. Head of Department, Prof Tinus Maritz, who has made major contributions to the Department's success, will be retiring at the end of 2015.

Prof Maritz obtained a BSc (Quantity Surveying) degree cum laude in 1973, a master's degree in 1987 and a doctorate in 2003, all from the University of Pretoria. He was appointed as a full-time lecturer in the erstwhile Department of Quantity Surveying in 1975, and was promoted to senior lecturer in 1987. In 2003, he was appointed associate professor, and promoted to Head of the Department of Construction Economics in 2007. He was also appointed Chairman of the School for the Built Environment in 2008.

He serves on various professional bodies and committees, such as the South African Council for the Quantity Surveying Profession (SACQSP) and the Association of South African Quantity Surveyors (ASAQS). He also serves on the technical and review committees of the Joint Building Contracts Committee (JBCC), the Standard System Joint Committee of the ASAQS, Master Builders South Africa (MBSA) and the ASAQS Preliminaries Committee. He is the ASAQS constituent representative on the JBCC.

In 2014, Prof Maritz received the ASAQS Gold Medal for outstanding service to the quantity surveying profession. This is a highly selective award and has been awarded to fewer than 10 people until now.

Prof Maritz has experienced a number of highlights during his tenure at the University of Pretoria. Among these is his establishment of a research culture in the Department, which did not exist before 2007. As a result, academic staff members are motivated to improve their qualifications. His hope is that all academic staff members will soon have a doctorate, which will be a first for the Department. He has also been involved in the development of the Construction Adjudication Certificate course through the campus enterprise Continuing Education at University of Pretoria (CE at UP). This is offered to senior law professionals and practitioners in the construction industry.

Another highlight has been his involvement in the compilation of model documentation and processes for quantity surveying practices. These include, inter alia, the Standard Method of Measuring Building Work (SMM), the Model Bills of Quantities, which is based on the 6th edition of the SMM, and Model Bills of Quantities for Small or Simple Buildings.

Prof Maritz hopes to maintain his involvement with the ASAQS as its representative on the JBCC and the International Coalition for Measurement Standards (ICMS).

Department of Construction Economics signs agreement with Australian partners

The University of Pretoria signed a Memorandum of Understanding (MoU) with the Australian Institute of Building (AIB) on 17 April 2015. The MoU aims to establish closer cooperation between the two organisations in an effort to enhance the professionalism of builders, construction managers, academics and graduates within the profession of construction management in Australia and South Africa.

Prof Tinus Maritz, Head of the Department of Construction Economics (left) and Norman Faifer, National President of the Australian Institute of Building, signed an MoU to establish closer cooperation between the two organisations.

The AIB's, National President, Norman Faifer, and Prof Tinus Maritz, Head of the Department of Construction Economics at the University of Pretoria, signed the agreement at the Pan Pacific Hotel in Perth, Australia. The agreement will initially be valid for two years, after which a formal review will be conducted.

Prof Maritz says the relationship between the two organisations will be characterised by collaboration, goodwill, a professional approach, cooperation and the constant pursuit of excellence.

He added: "Our activities will be conducted with respect for each other's systems of work, structures, culture and values, and will support operations being carried out in an effective and integrated manner. To measure the progress and success of the agreement, we will meet annually to review the understanding and to identify opportunities to strengthen the relationship."

The AIB and UP have agreed to exchange information relevant to the development of the building and construction management profession in Australia and South Africa in order to facilitate an understanding of each other's work.

This will include the following:

- Forwarding information distributed to their respective organisations, such as magazines and newsletters, to a liaison officer nominated by each organisation.
- Promoting each other's jointly organised continuing professional development events on both organisations' respective websites.
- Promoting the agreement on their respective websites, including a link from each website to the other party's website.
- Establishing annual formal contact to review the agreements and identify opportunities to strengthen the relationship

Both organisations are eager to enter into additional agreements to support collaborative activities and enhance their commitment to the construction management profession. "Our aim is to promote the value of membership to professional institutes, and student and graduate engagement in student groups and industry, as well as to encourage research in the field of construction management," says Prof Maritz.

Architecture welcomes new Head of Department

In order to remain a flagship member of the University of Pretoria, the Department of Architecture needs a suitably qualified and dedicated leader. Prof Chrisna du Plessis has been appointed as the new Head of the Department of Architecture. She takes the reins from Prof Roger Fisher, who was appointed as Acting Head of Department after the passing of Prof Karel Bakker on 19 November 2014.

Prof Du Plessis commenced her academic career at the University of Pretoria, where she obtained a bachelor's degree in Architecture in 1991 and a master's degree in Architecture (cum laude) in 1999. She obtained a PhD from the University of Salford in Manchester, England, in 2009. In 2010, she was awarded an honorary doctorate by the Chalmers University of Technology in Göteborg, Sweden.

After completing her first degree, Prof Du Plessis practised as a development consultant specialising in low-cost housing development and ecotourism. Between 1996 and 1998, she was employed as a part-time lecturer in the Department of Architecture at the University of Pretoria. In 1997, she joined the Council for Scientific and Industrial Research (CSIR) as an urban researcher. She was promoted to senior specialist in 2000 and to principal researcher in 2005. Prof Du Plessis accepted a part-time position in the Department of Construction Economics at the University of Pretoria and was appointed full-time as an associate professor in 2011.

Prof Du Plessis is an expert in built environment sustainability and has applied her expertise in the disciplines of housing, construction industry performance, urban/human settlement development and infrastructure design. She has served on the scientific committees of 19 international conferences and has acted as a juror for national and international architecture competitions including the Holcim Foundation Sustainable Construction Award and the European Solar Decathlon.

Prof Du Plessis is an expert in built environment sustainability and has applied her expertise in the disciplines of housing, construction industry performance, urban/human settlement development, and infrastructure design.

In 2012, she received the Salford Alumni Achievers Award and she has been awarded the prestigious Chalmers' Jubilee Visiting Professorship for 2016. Prof Du Plessis has recently published *Designing for hope: pathways to regenerative sustainability* with Routledge and produced a documentary, *The regenerates*.

Her vision for the Department is to build on existing strengths to grow a department that is internationally recognised for producing graduates with skills that are relevant to the challenges of the 21st century. She hopes that the research emanating from this department will be instrumental in creating a resilient and regenerative built environment that will contribute to the positive development of society.

She hopes to achieve this by revising the curriculum to ensure its continued relevance to the professions, pursuing opportunities for international staff and student exchange and establishing greater research synergies and collaboration with the other departments in the School for the Built Environment and international partners.

→ *Prof Chrisna du Plessis (left) in conversation with Prof Roger Fisher.*

Industry leader heads Materials Science and Metallurgical Engineering

The Department of Materials Science and Metallurgical Engineering welcomes Prof Roelf Mostert, who was appointed Head of Department with effect from 1 April 2015. Prof Mostert has vast industry experience, which will be utilised to the benefit of the Department, its students and the University as a whole.

His specialisation is in the field of materials integrity and equipment life extension. He has extensive global experience in both facility integrity management (including asset management systems) and the life assessment and extension of oil, gas, power and refinery plants and equipment. He has often provided expert evidence regarding disputes concerning the failure of materials and components – a field often referred to as forensic engineering.

Prof Mostert is an alumnus of the University of Pretoria. He received his BSc Metallurgy and BSc (Hons) Metallurgy degrees from his alma mater in 1979 and 1980 respectively, followed by a master's degree (in 1983) and PhD (in 1989) – also from UP – with a dissertation on research into steel transformation, heat treatment, hardenability and new steel development. He has been registered as a professional engineer with the Engineering Council of South Africa (ECSA) since 1984. He is also a member of the Specialist Technical Committee: Risk-based Inspection Implementation of the South African National Accreditation System.

He launched his career in 1980 at the erstwhile Iscor Limited (which became Mittal Steel South Africa in 2005, now known as ArcelorMittal), where he worked as a principal research officer. Here he was part of the research and development team developing and/or industrialising new steels. In 1988, he joined Denel at the Lyttleton Engineering Works as manager of the Materials Treatment Plant. In 1990, he established a partnership known as Metallurgical Site Support, which specialised in heat treatment and inspection services to the petrochemical and associated industries. The company performed work on all the refineries in South Africa, including those in Sasolburg, Secunda, Durban, Cape Town and Mossel Bay (Mossgas).

In 1996, after Metallurgical Site Support was bought out by the global Cooperheat Group of Companies, he was appointed Director, and later Managing Director, of InnoMet. During this time, he initiated and participated in the acquisition of Metlab 82, a prominent metallurgical laboratory in the East Rand. His period with this company included several highlights, culminating in his involvement in the forensic analysis of the Injaka Bridge Collapse, arguably the most extensive forensic engineering analysis in South African history. This investigation concerned, among others, the quality of welds and the acceptability of weld defects. Finite element analyses and defect acceptability studies were also performed.

> His industry experience has made him a recognised expert in industrial integrity engineering.

The expertise he gained at InnoMet led to his appointment in 2012 as chief engineer and Business Unit Manager of Megchem Engineering and Drafting Services (Pty) Ltd. Here he was primarily responsible for developing a business unit focusing on fitness for service and failure, and forensic engineering. He also executed a number of local and international engineering integrity survey projects.

His industry experience has made him a recognised expert in industrial integrity engineering, particularly with regard to the failure of materials and materials degradation, which will be of immeasurable value in the teaching, research and consultation activities of the Department of Materials Science and Metallurgical Engineering.

Prof Mostert has also been very active on the research and innovation front. His research has been cited in a handbook on the bainite transformation in steels, which was published by the Institute of Materials in the United Kingdom.

His research interests include steel degradation mechanisms, fitness for service evaluations, failure analyses, environmentally assisted cracking and alternate dispute resolution. He has delivered papers at a number of conferences both locally and internationally, and has authored and co-authored articles in peer-reviewed journals, as well as numerous technical and policy reports. Furthermore, Prof Mostert has six registered product patents to his credit, as well as the development of a high-ballistic resistance steel plate prototype, produced at two locations in Europe and tested in South Africa.

As Head of Department, Prof Mostert plans to strengthen research in those areas that are already well established in the Department. He also plans to expand research related to globally relevant issues in the mining industry, such as the integrity of materials and components, particularly as these issues relate to the degradation and fracture of materials, as well as their investigation and prevention.

Collaboration with the other departments at the University that form part of the mineral sciences value chain (Geology and Mining Engineering), participation in the activities of the newly established Mining Resilience Research Institute, and fostering cooperation with and developing joint initiatives with international research and academic institutions will ensure that the Department continues to make a meaningful contribution in an industry that plays such an important role in the economic wealth of the country.

Materials Science and Metallurgical Engineering engages in continental collaboration

Dr Bruno Roberts of the Jomo Kenyatta University of Agriculture and Technology in Kenya during a recent exploratory visit to the University of Pretoria.

The University of Pretoria's Department of Materials Science and Metallurgical Engineering has signed a Memorandum of Understanding (MoU) with the Jomo Kenyatta University of Agriculture and Technology (JKUAT) in Kenya, which will result in joint teaching, research and technological development between the two institutions for a period of five years.

JKUAT provides higher learning facilities for university education, participates in the discovery, transmission, preservation and enhancement of knowledge, and stimulates the intellectual participation of students to further the economic, agricultural, professional and cultural development of Kenya. Its mission is to provide accessible, quality university education, training, research and innovation in order to provide leaders in the fields of agriculture, engineering, technology, enterprise development, health and other applied sciences to suit the needs of a dynamic world.

The collaboration entered into between the two institutions is aimed at fostering cooperation and the development of joint initiatives aimed at achieving the following:

- Boosting and enhancing development and industrialisation through research, training, innovation, technological development, and commercialisation and marketing in the areas of engineering, technology and related fields.
- Providing an instrument for establishing various collaborative initiatives for the growth and mutual benefit of the two institutions.
- Enhancing the professional skills and networking of staff of both institutions through training, staff and student interactions, and the exchange of experiences and information.
- Providing a basis for the promotion of materials and metallurgical engineering in Kenya and South Africa.

The institutions will collaborate in terms of the sharing of physical facilities, institutional capacity-building, staff exchange and attachment, the exchange and dissemination of information, and research, innovation and technology development.

Faculty Concert Evening is a huge success

The annual concert evening of the Dean of Engineering, Built Environment and Information Technology is an annual event to thank the Faculty's industry partners, staff and students for their ongoing support and contribution to its success.

The theme of the concert for 2015 was "New Beginnings", and featured a delightful compilation of melodies performed by the University of Pretoria Symphony Orchestra (UPSO). All the tunes were especially arranged for this concert by Matthijs Pienaar. For the evening's performance, Gerben Grooten, conductor of the UPSO, put together a unique orchestra to reflect the sounds of South Africa, displaying the rainbow nation and exuding hope, love and compassion.

In his welcoming message, Prof Sunil Maharaj, Dean of the Faculty of Engineering, Built Environment and Information Technology, expressed the wish that the music should "remind us of what can be achieved by the coming together of gifted, inspired individuals, cooperating through hard work and dedication to create and recreate these great works of art, reaching far beyond what anyone could have achieved alone."

Music is a moral law. It gives soul to the universe, wings to the mind, flight to the imagination, and charm and gaiety to life and to everything.
– Plato

The roots of industrial engineering – Blaise Pascal and Pierre de Fermat

Compiled by Prof Paul Kruger

The history of human endeavour abounds with examples of the successful collaboration between two individuals leading to extraordinary achievements that they may not have reached as the sum of their individual efforts.

Examples are evident in a number of diverse fields: Pierre and Marie Curie (science), Frank and Lillian Gilbreth (engineering), Fischer Black and Myron Scholes (economics), Orville and Wilbur Wright (engineering), Francis Crick and James Watson, (science), Robert and Elizabeth Browning (literature), Richard Rodgers and Oscar Hammerstein (music) and Rudolf Nureyev and Margo Fonteyn (ballet), to name but a few. However, the world of mathematics/statistics is rather sparse in this regard. One possible exception is the collaboration between Blaise Pascal and Pierre de Fermat, a collaboration that led to the development of Probability Theory.

Pascal: the son of a tax farmer

Blaise Pascal (1623–1662) was born in Clermont-Ferrand, France, the third of four children and the only son of Etienne Pascal and Antoinette Begon. His mother died when he was only three years old. He was a child prodigy who was tutored in mathematics by his father, while the Jansenists (a Catholic sect) worked on his soul. Pascal's father was a judge and a "tax farmer". He bought the right to collect as much as possible of the outstanding taxes from tax defaulters from the government. His father had some unorthodox educational views and removed all the books on mathematics from the house, ostensibly to prevent Pascal from working too hard (a copy of Euclid's *Elements* was provided to Pascal when he was 12), thus only managing to intrigue the young Pascal. At the age of 16, he wrote a paper on the mathematics of the cone, which impressed even the great René Descartes (1596–1650), who helped him finish and publish the paper in 1640.

> "All men's miseries derive from not being able to sit in a quiet room alone. The heart has its reasons of which reason knows nothing."
>
> Blaise Pascal

In 1642, Pascal developed a mechanical calculator, which he called the Pascaline, to speed up arithmetic calculations for his father. Because of the Pascaline, Pascal is sometimes credited with inventing the first mechanical calculator – and by implication – starting the computer age. However, several similar attempts

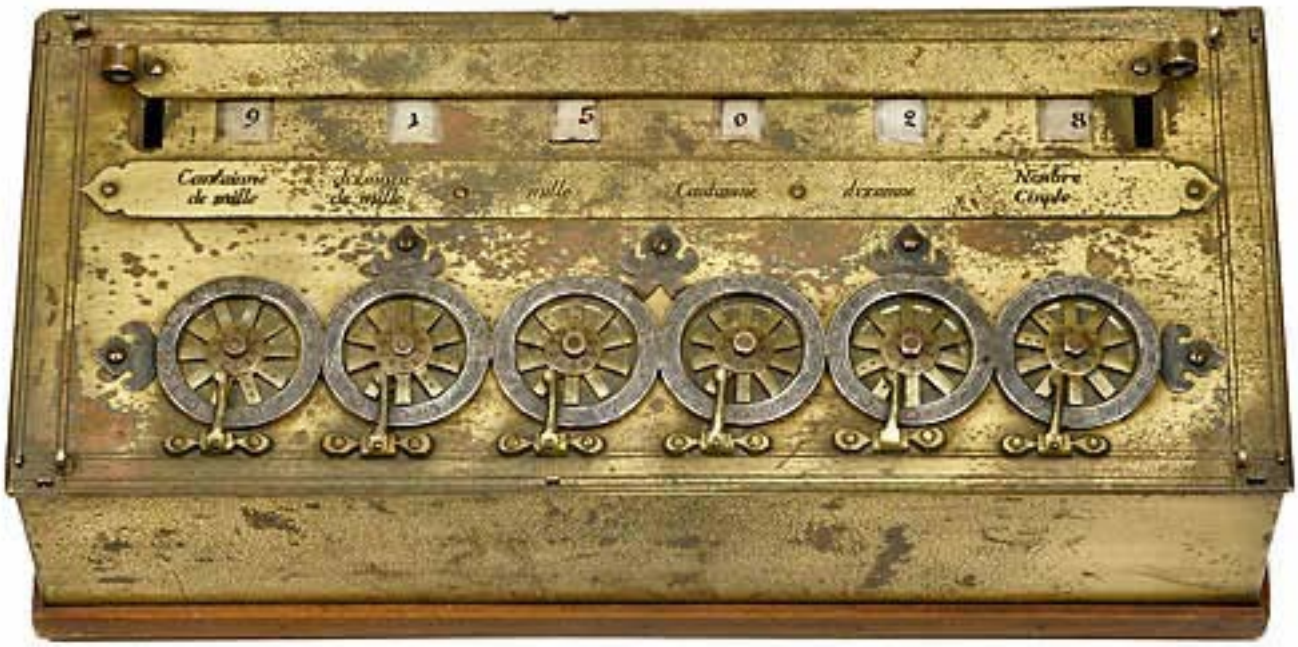
predated the Pascaline. In 1617, John Napier (1550–1617), the inventor of logarithms, designed a mechanical calculator known as "Napier's bones". Napier's bones was not based on logarithms, but on some rather old Arabic mathematical techniques. In 1622, William Oughtred (1574–1660) invented the first slide rule using Napier's logarithms to effect multiplication by addition. In 1623, Wilhelm Schickard (1592–1635) designed a calculator based on Napier's bones. Neither of the two machines that he built survived. Whether Schickard or Pascal was the inventor of the first mechanical calculator is still a contentious issue.

The design of the Pascaline was somewhat unique and managed to overcome most of the problems of its predecessors. Although it was primarily intended as an adding machine, it could perform multiplication by successive addition, a rather laborious process. Between 1642 and 1645, Pascal manufactured and tested more than 50 prototypes before producing some 20 machines based on his "final" design, even attempting to sell them, albeit without much success. Nine of the original machines survived and are on display in various museums. The discovery of the tenth one is the "holy grail" of collectors of mechanical calculators. Numerous replicas are on the market and may sell for anything between $20 000 and $50 000. The mechanical calculators in general use during the first half of the 20th century rather closely resembled the Pascaline.

Pascal contributed significantly to science in the fields of hydrostatics and hydrodynamics, especially with regard to his numerous experiments expanding and generalising the work of Evangelista Torricelli (1608–1647) on atmospheric pressure. In 1647, Pascal became embroiled in a bitter dispute with other scientists, mainly because of his insistence on the possible existence of a vacuum, a notion that was abhorrent to most scientists and philosophers of the time. After all, the concept of "something" that is "nothing" is difficult to accept, even for a philosopher. In a letter to Christiaan Huygens (1629–1695) (the author of the first book on statistics), René Descartes even wrote that Pascal "... has too much vacuum in his head", but later – somewhat reluctantly – admitted that Pascal was probably correct.

Pascal was a very religious man who, in his old age (he died at the age of 39), was convinced that the practice of mathematics was a mortal sin, possibly due to the influence of the Jansenists. In an effort to atone for his "sins", he spent extended periods in the monastery were his one sister was a nun. It was during these periods that he wrote extensively on philosophy and religion, specifically his famous *Lettres Provinciales* and *Pensées,* which are considered to be literary masterpieces, which even a writer such as Voltaire used for inspiration. In this way, Pascal may be considered as one of only a few people who has contributed significantly to mathematics, statistics, philosophy and religion. *Pensées* contains the so-called "Pascal's wager", in which he could not refrain from bringing some mathematical logic to light, even on his religious writings: "If God does not exist, one will lose nothing by believing in Him, while if He does exist, one will lose everything by not believing ... we are compelled to gamble!" In this way, he formulated an important statistical concept, namely an "expected value", presently used widely in performing risk analyses.

Pascal's deep religious convictions are poignantly illustrated by the following, possibly apocryptical story: In 1654, he was



→ *An original Pascaline.*

"I have made this letter longer than usual, only because I have not had the time to make it shorter. Men never do evil so completely and cheerfully as when they do it from religious conviction."

Blaise Pascal

contemplating marriage when the horses of his carriage were frightened and jumped over the rail of a bridge. Pascal was only saved by the fact that all the traces broke, leaving him alive on the bridge. Interpreting this incident as a sign of divine origin, Pascal promptly decided never to get married, and he never did. He wrote this pledge on a piece of paper, which he sewed in the lining of his coat, transferring it carefully whenever he changed clothes.

Pascal had many diverse interests, even trying to create a perpetual motion machine. His complex personality has been described as "precocious, stubbornly persevering, a perfectionist, pugnacious to the point of bullying, ruthless, yet seeking to be meek and humble".

In honour of his scientific work, the name Pascal was given to the International System of Units (SI) unit of pressure, the programming language Pascal and the Pascal triangle, even though this triangle was known to the Chinese some centuries earlier.

Pascal was never a very healthy person and suffered from migraines and severe abdominal pains for most of his adult life. He died from what was probably some kind of tumour at the age of 39.

De Fermat: the prince of amateurs

Dominique Fermat, the father of Pierre de Fermat (1601–1665), was a wealthy leather merchant and second consul of Beaumont-de-Lomagne in France. His mother was either Francoise Cazeneuve or Claire de Long. He had a brother and two sisters, and attended the universities of Toulouse and Bordeaux where he studied mathematics, producing important work on maxima and minima. He moved to the University of Orléans where he received a degree in civil law. He purchased the offices of the Councillor of the Parliament in Toulouse and became a lawyer and government official. Because of the office he held, he was entitled to change his name from Pierre Fermat to Pierre de Fermat. In 1638, he was appointed to a higher chamber, and in 1652, he was promoted to the highest level in the criminal court with further promotions following in quick succession. This meteoric rise through the ranks may have been at least partly due to the prevailing custom of awarding promotions on the basis of seniority, and De Fermat's colleagues and seniors were dying of the plague in droves. De Fermat himself was struck down by the plague in 1653. As in the case of Mark Twain (1835–1910), it was reported that he had died, but this report proved to be wrong and he managed to survive.

De Fermat is sometimes credited with the invention of calculus, and his work on minima and maxima and tangents certainly laid the foundations for the efforts of Isaac Newton (1643–1727) and Gottfried Wilhelm von Leibniz (1646–1716).

De Fermat was a successful and rich lawyer, for whom mathematics was a sideline and something to be used to exercise and amuse his extraordinary mathematical genius. Most of his work was communicated by way of letters to friends, often as theorems, statements or even puzzles, without providing the solutions, leaving it to Leonard Euler (1707–1783) to find them 100 years later. This was at least partly due to the fact that he experienced severe problems in publishing his work for the simple reason that he had a total disinterest in editorial polish. He even once asked Pascal to help him prepare a paper for publication, but Pascal promptly refused to act as De Fermat's editor.

Shortly before his death, De Fermat was reading in the famous *Arithmetica* of Diophantus about a problem that may be summarised as follows: It is well known that the equation, $x^2 + y^2 = z^2$ has an infinite number of positive integer solutions, the so-called Pythagoras triplets. However, is this also true for $x^n + y^n = z^n$ for $n > 2$? In the margin of the book, De Fermat wrote: "I have discovered a truly remarkable proof of this theorem, which this margin is too small to contain." This statement became known as "De Fermat's last theorem" and provided numerous mathematicians with a challenge – and some irritation and frustration – to either prove or disprove De Fermat's last theorem for 357 years. Ironically, Carl Friedrich Gauss (1777–1855), "the prince of mathematics", declared somewhat peevishly that he had very little interest in De Fermat's theorem, since "... I could easily lay down a multitude of such propositions, which one could neither prove nor disprove". Andrew Wiles, the British mathematician

→ *Blaise Pascal.*

→ *Pierre de Fermat.*

from Princeton, only recently (1993) proved the correctness of "De Fermat's last theorem". Wiles's proof is almost certainly not the same as the one De Fermat had in mind, simply because De Fermat could not have had any knowledge of the mathematics used and developed by Wiles. Recently (2014), Tom Ballard claimed to have discovered a so-called "short-form" proof to De Fermat's last theorem, which has not been accepted or rejected to date. If it is declared to be acceptable, it may be similar to what De Fermat had in mind, since it seems to be based mainly on geometry and number theory, both subjects with which De Fermat was well acquainted. Some doubt exists as to whether De Fermat ever had "proof". He made a habit of teasing the mathematical community by confronting them with bold mathematical statements and theorems without providing any proof. Therefore, De Fermat's last theorem may be no more than a mischievous hoax. However, De Fermat's statement motivated numerous mathematicians to spend countless hours working on a possible proof and, in the process, developed a significant body of new mathematical theory. Thus, in this way, whether a hoax or not, "De Fermat's last theorem" may be seen as De Fermat's lasting legacy.

Pierre de Fermat died of unknown causes at the age of either 57 or 58 in Castres, France.

Both Pascal and De Fermat are rightfully famous and respected for their individual accomplishments, but their greatest and lasting contribution may be found in their mutual achievements in establishing the mathematics of probability theory. Chevalier de Méré, a nobleman with an insatiable appetite for gambling, solicited Pascal's help in "improving the odds in gambling". The problem, as stated by De Méré, albeit somewhat innocuous and facetious, was how to divide the "pot" among the players if a game of chance is prematurely terminated. Pascal turned to De Fermat for support, and thus started an amazing journey of discovery into the mathematics of chance. Between the two of them and by way of the exchange of 24 letters, all but the first one have survived. They not only put the principles of probability theory on a firm scientific basis, but finally got rid of the medieval notion that the roll of a die was in some way controlled by the gods.

Nowadays, probability theory is an integral part of many topics in engineering and science, including reliability engineering, quality control, stochastic modelling, forecasting, actuarial science, quantum mechanics, particle physics and – obviously – lotteries and gambling.

This article is dedicated to the memory of Prof Kristiaan Adendorff, who not only initiated, but also kindled and shared my interest in the history of mathematics over many years.

This article is adapted primarily from Against the gods: the remarkable story of risk *by P L Bernstein;* Fermat's last theorem *by Simon Singh; http://www-history.mcs.st-and.ac.uk; http://en.wikipedia.org; and many more easily accessible websites.*